E82-10192
NASA CR-161047

Progress Report for NASA
Contract NAS9-15476

ANALYSIS OF SCANNER DATA FOR CROP INVENTORIES

Program Manager
ROBERT HORVATH

Program Area Managers
RICHARD C. CICONE
RICHARD J. KAUTH
WILLIAM A. MALILA

15 NOVEMBER 1980 -
14 FEBRUARY 1981

(E82-10192) ANALYSIS OF SCANNER DATA FOR CROP INVENTORIES Progress Report, 15 Nov. 1980 - 14 Feb. 1981 (Environmental Research Inst. of Michigan) 141 p HC A07/MF A01 CSCL 02C G3/43

N82-22626

Unclas
00192

ENVIRONMENTAL
RESEARCH INSTITUTE OF MICHIGAN
BOX 8618 • ANN ARBOR • MICHIGAN 48107

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Progress Report for 15 November 1980 - 14 February 1981		5. Report Date April 1981 6. Performing Organization Code
7. Author(s) R. Horvath, R. Cicone, R. Kauth, W. Pont, B. Thelen, A. Sellman		8. Performing Organization Report No. 152400-4-P
9. Performing Organization Name and Address Environmental Research Institute of Michigan P.O. Box 8618 Ann Arbor, Michigan 48107		10. Work Unit No. 11. Contract or Grant No. NAS9-15476
12. Sponsoring Agency Name and Address National Aeronautics & Space Administration Johnson Space Center Houston, Texas 77058 Attn: Mr. I. Dale Browne/SG32		13. Type of Report and Period Covered Progress Report 15 November 1980 - 14 February 1981 14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

This report summaries the progress on subject contract during the first quarter of the 1981 contract year. It is comprised of the presentations supporting quarterly project management reviews and a quarterly technical interchange meeting.

17. Key Words Crop Inventory, Landsat, Sampling, Temporal Profile Fitting, Machine Labeling, Area Estimation, Through-the-Season Estimation, Small Fields, Argentina	18. Distribution Statement

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	139	

PRECEDING PAGE BLANK NOT FILMED

PREFACE

The following report serves as the Quarterly Report for Contract NAS9-15476 which is entitled "Analysis of Scanner Data for Crop Inventories". This report describes the work carried out under that contract for the period 15 November 1980 - 14 February 1981.

Work on this contract is performed in the Infrared and Optics Division directed by Mr. Richard R. Legault. Mr. Robert Horvath is the Program Manager for this contract.

This contract, performed by the Environmental Research Institute of Michigan (ERIM) for the Space and Life Sciences Directorate of the NASA/Johnson Space Center, is part of the multi-agency AgRISTARS Program and supports both the Supporting Research (SR) and Foreign Commodity Production Forecasting (FCPF) Projects within AgRISTARS. The overall goal of AgRISTARS is to determine the usefulness, cost and extent to which aerospace remote sensing data can be integrated into existing or future U.S. Department of Agriculture (USDA) systems to improve the objectivity, reliability, timeliness and adequacy of information required to carry out USDA missions.

PRECEDING PAGE BLANK NOT FILMED

ERIM

TABLE OF CONTENTS

ACTIVITIES AND ACCOMPLISHMENTS

In Support Of

SUPPORTING RESEARCH PROJECT

Environmental Research Institute of Michigan
University of California at Berkeley

SR Quarterly Project Review

10 March 1981

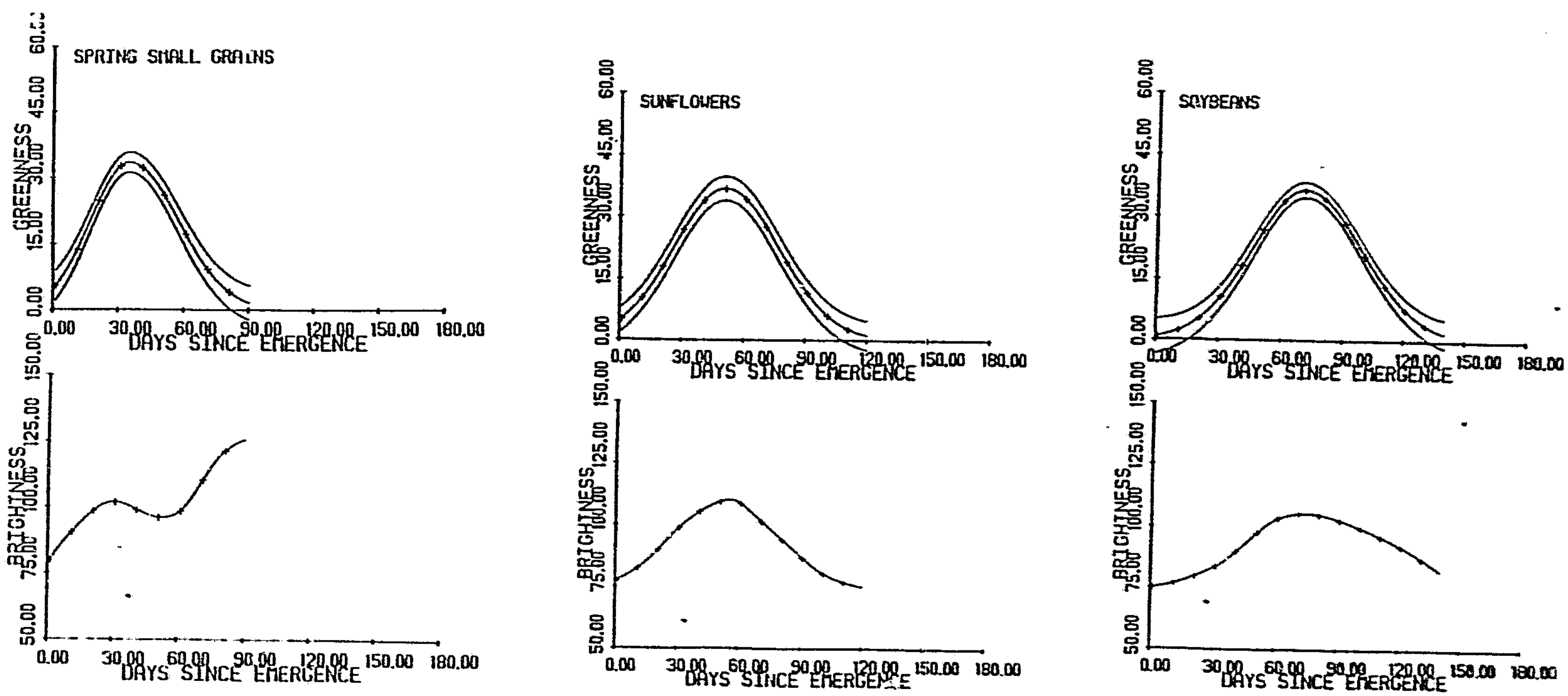
PRESENTATION OUTLINE

ACCOMPLISHMENTS:

- Machine-Oriented Small Grains Labeler T&E
- Argentina Ground Data Collection

GENERAL CONCEPTS OF SMALL GRAINS LABELER

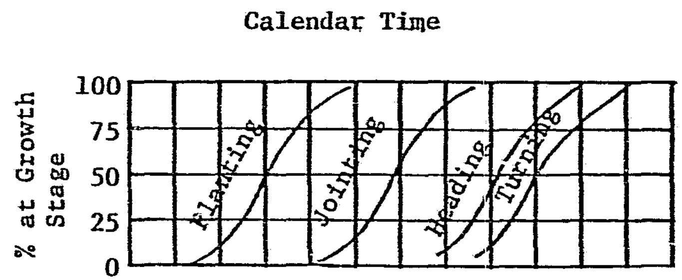
- Temporal-Spectral Profiles
  - Characterize continuous patterns of crop spectral development
  - Landsat observations represent discrete samples from continuous patterns



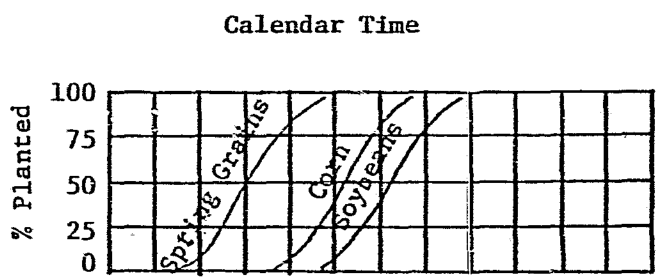
GENERAL CONCEPTS (Continued)

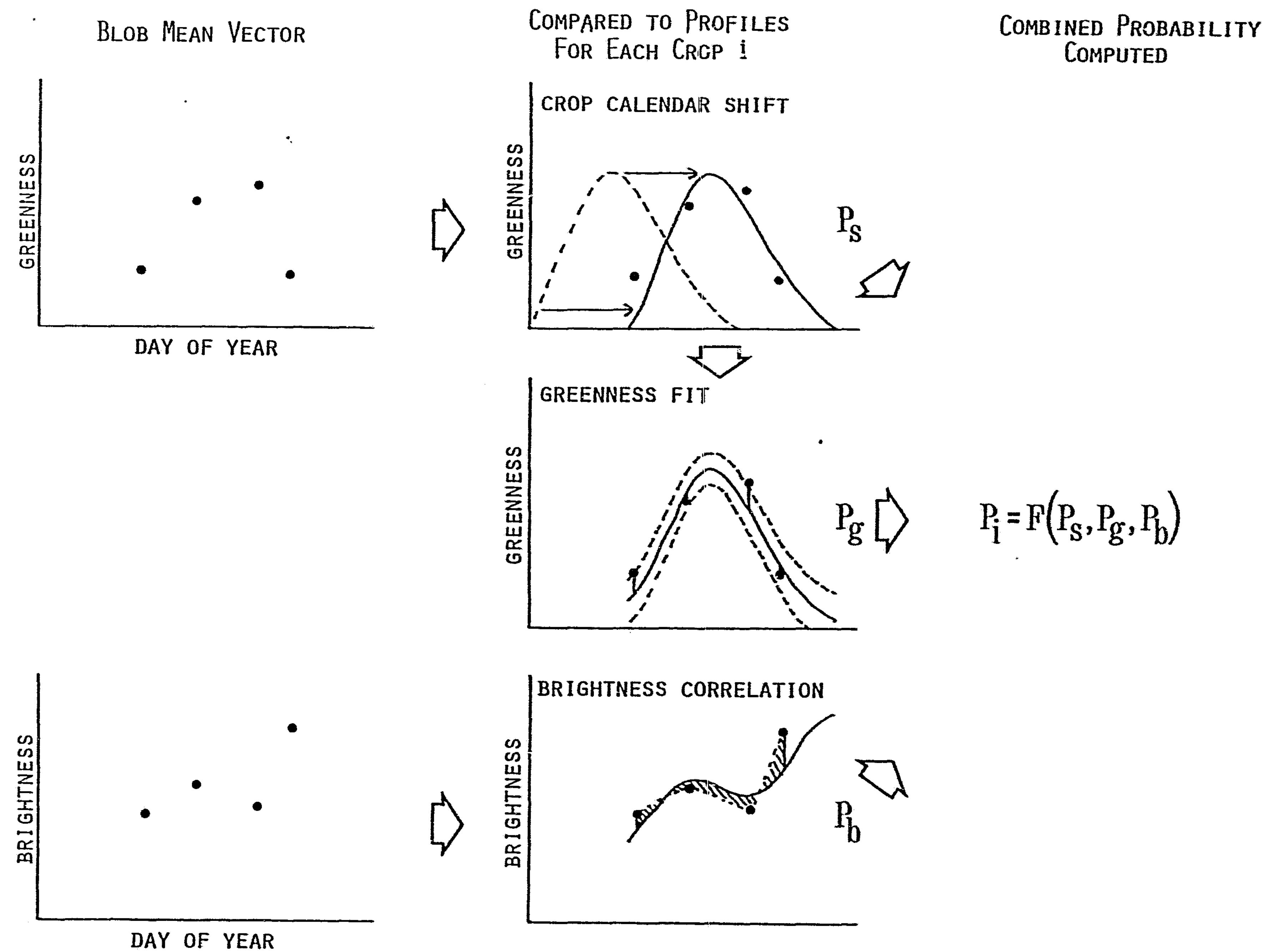
- Crop Calendar Shift Estimation
  - Adjust for planting date differences of fields within a crop type

Spring Grain Crop Calendar



  - Extract information of use in crop identification




BLOB MEAN VECTOR
COMPARED TO PROFILES FOR EACH CROP i
COMBINED PROBABILITY COMPUTED
GREENNESS
DAY OF YEAR
CROP CALENDAR SHIFT
GREENNESS
P_s
GREENNESS FIT
GREENNESS
P_g
$P_i = F(P_s, P_g, P_b)$
BRIGHTNESS
DAY OF YEAR
BRIGHTNESS CORRELATION
BRIGHTNESS
P_b

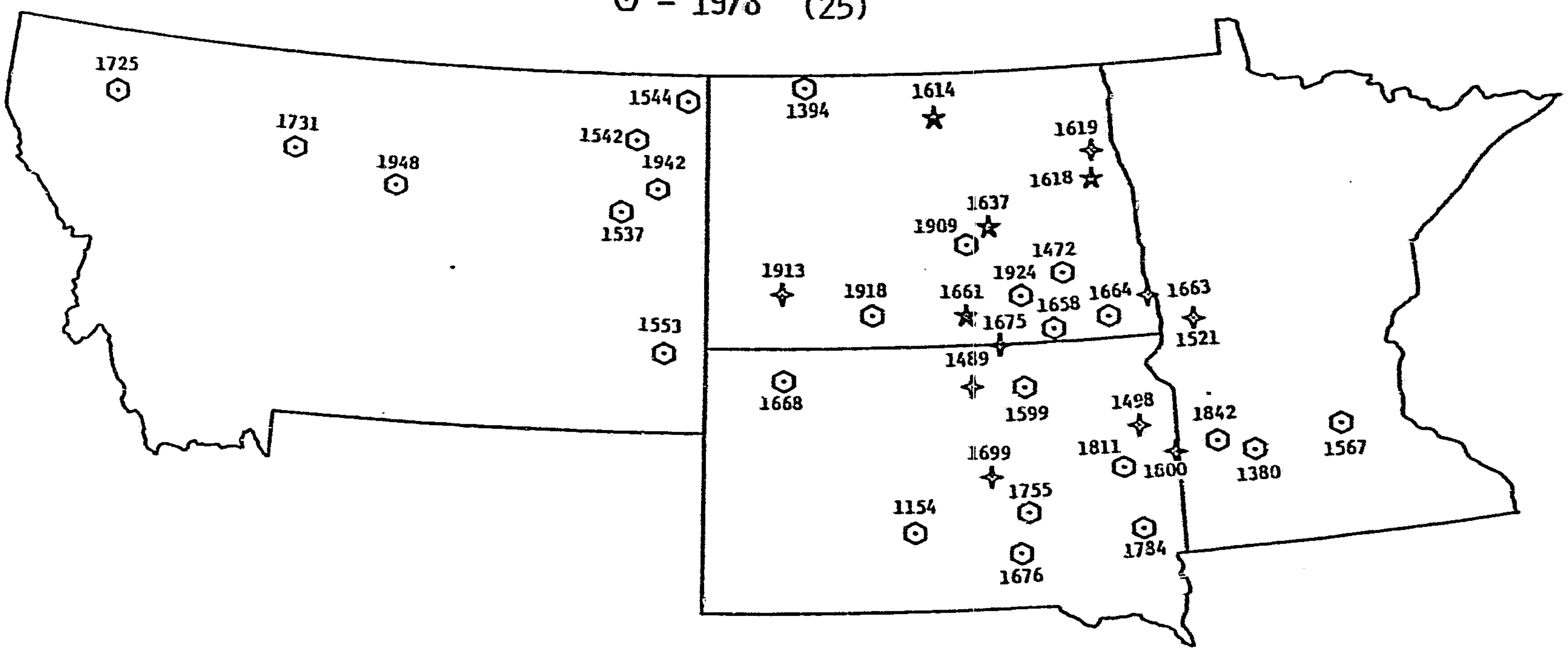
DESCRIPTION OF TEST DATA SET

38 Segments, 3 Years (1976-78)

☆ = 1976 (4)

✧ = 1977 (9)

⊙ = 1978 (25)



TEST AND EVALUATION RESULTS

Labeling Accuracies

- Overall Grain Labeling Accuracies Up to 89%
- Non-Grain Accuracy (% of Non-Grain <u>Not</u> Called Grain) Tends to be Inversely Related to Grain Accuracy
- Optimal Balance and Accuracy

  68% Grain Correct

  63% Non-Grain Correct

TEST AND EVALUATION RESULTS (Continued)

- Labeling Error Characterization
  - Grass profile was primary competitor for grain blobs
  - Grass was primary error class for grain profile
- Test-Statistic Weightings
  - Use of all three probability variables was best
  - After time shifting based on Greenness profiles
    - Brightness correlation was best single discriminator for grain
    - Greenness fit was worst
- Profile Set Configurations
  - Grain labeling accuracy maximized (and non-grain accuracy decreased) by omitting grass and flax profiles
- Ability to Assign Labels
  - Minimum of three acquisitions required in range of growing season
  - For test and developmental data combined, 57% of blobs were labelable
  - Most segments were either labelable or not:
    - 16 segments were 0-20% labelable
    - 31 segments were 80-100% labelable

TEST AND EVALUATION RESULTS

Labeling Error Characterization

Errors of Omission - Grains Called Non-Grain

- Grass Profile is Primary Competitor for Grain Blobs
  - With both profiles present, approximately equal numbers of Grain blobs are assigned to each
  - Elimination of Grass profile increases Grain accuracy ~15%
- Flax Profile is Second Most Common Competitor
  - Greenness profiles are identical
  - Average of 10-15% of Grains are called Flax
  - Elimination of Flax profile increases Grain accuracy ~10%
- Elimination of Both Profiles Increases Grain Accuracy 25-30%
- Other Profiles Draw Less Than 10% of Grain Blobs

TEST AND EVALUATION RESULTS

Labeling Error Characterization

Errors of Commission - Non-Grains Called Grain

- Grass is Primary Error Source
  - ~25% called Grain
  - With no Grass profile, 50-75% called Grain
- Flax - 40-50% Called Grain
- Sunflowers - 30-60% Called Grains
- Corn and Soy - 15-20% Called Grain
- Commission Errors Increase When Grass and/or Flax Profiles are Eliminated

TEST AND EVALUATION RESULTS

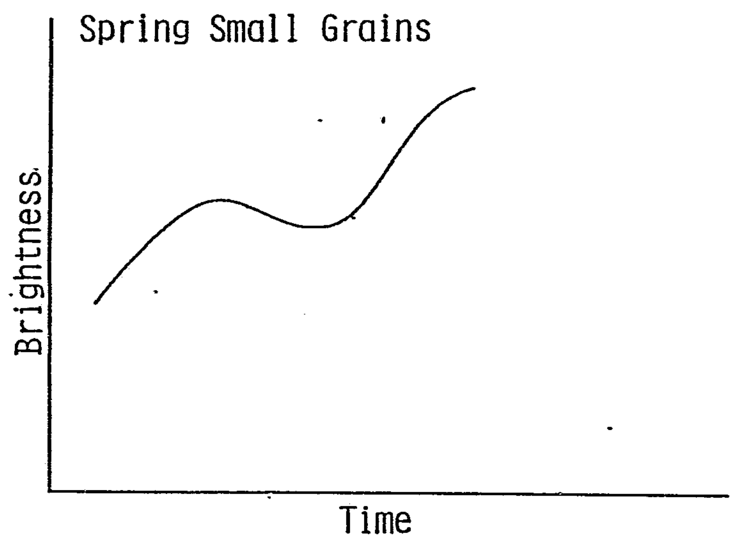
- Labeling Error Characterization

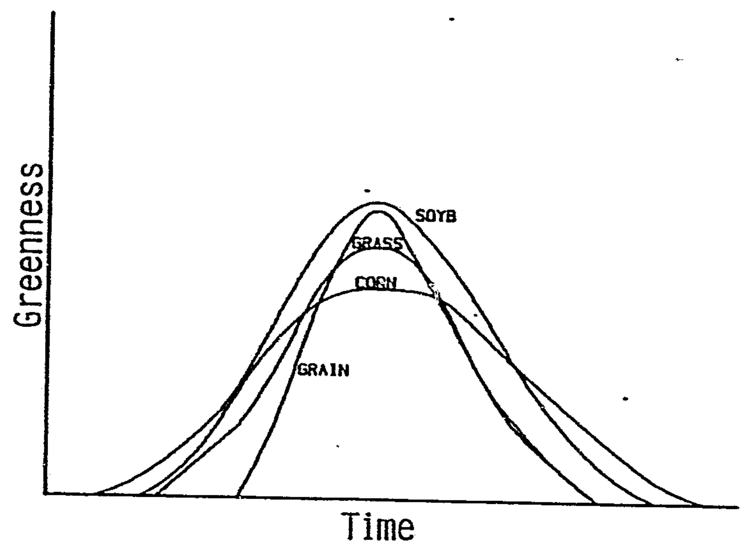
Comparison of Test-Statistic Weightings

- Weightings Which Utilize Only One of the Three Probabilities or Most Pairs are Inferior to Those Utilizing All Three

- Brightness correlation is the best single discriminator for Grain

- Greenness fit is the worst single discriminator for Grain





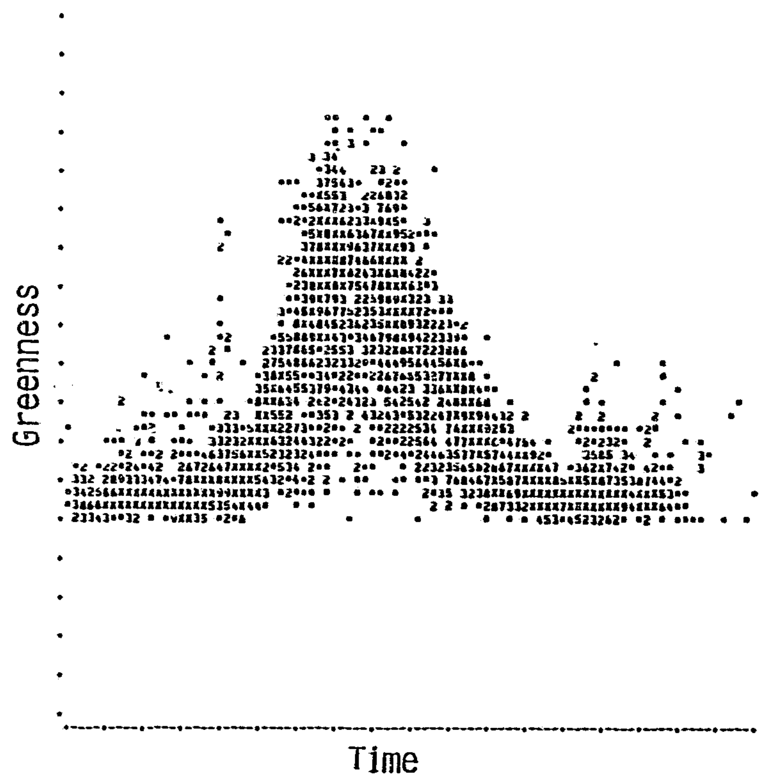
TEST AND EVALUATION RESULTS

Qualitative Component Evaluation

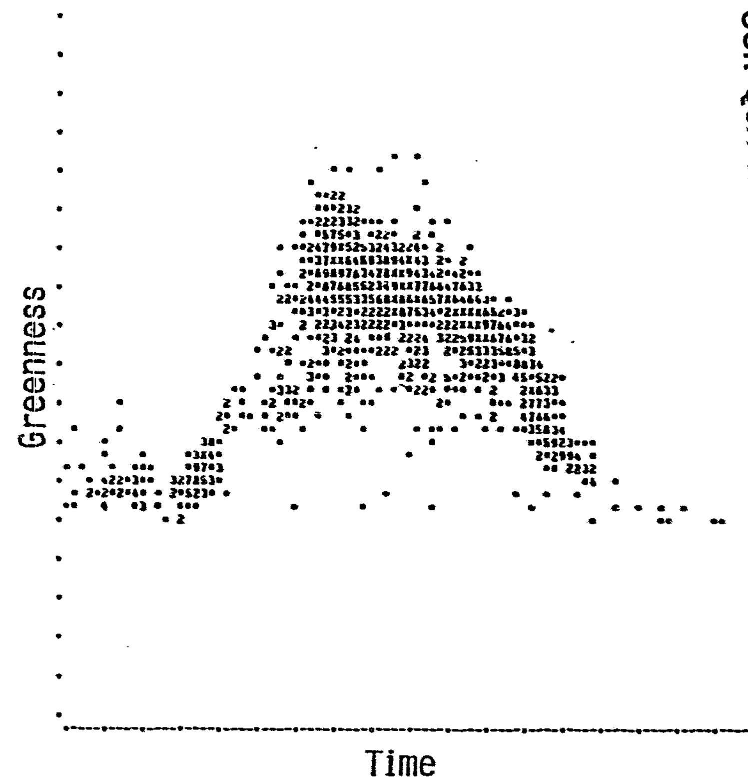
Profiles and Profile-Fitting

- Most Data for a Given Crop (Based on Ground Truth) Do Follow the Expected Pattern of Greenness Development

Grain



Corn



ORIGINAL PAGE IS
OF POOR QUALITY

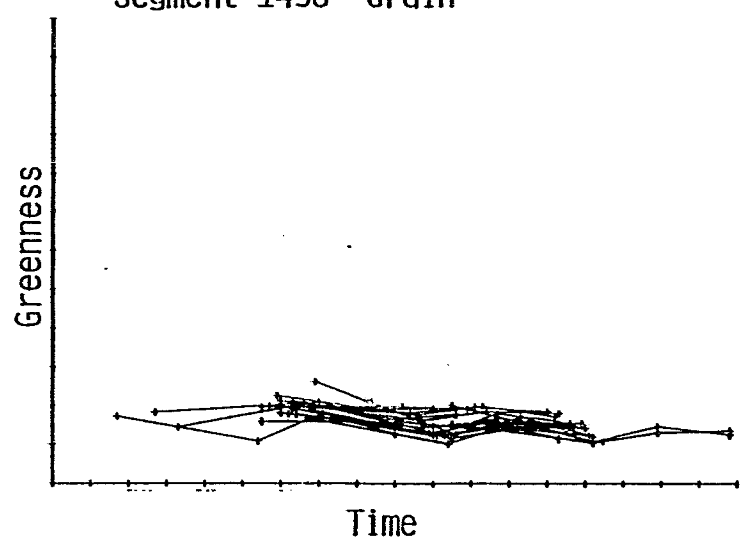
TEST AND EVALUATION RESULTS

Qualitative Component Evaluation

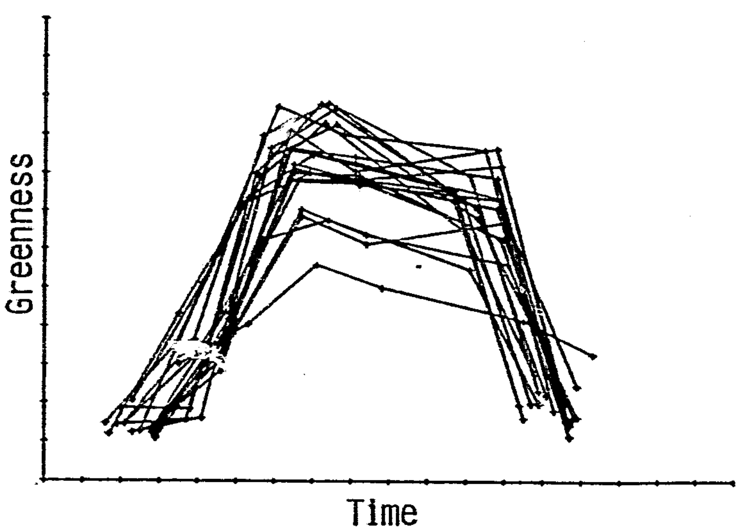
Profiles and Profile-Fitting (Continued)

- Fields of a Particular Crop Type (Based on Ground Truth) Do Not Always Follow the Characteristic Spectral Development Pattern of the Crop
  - Misregistration
  - Ground truth errors
  - Abandonment, early cutting, hail damage, etc.

Segment 1498 Grain



Segment 1619 Grain

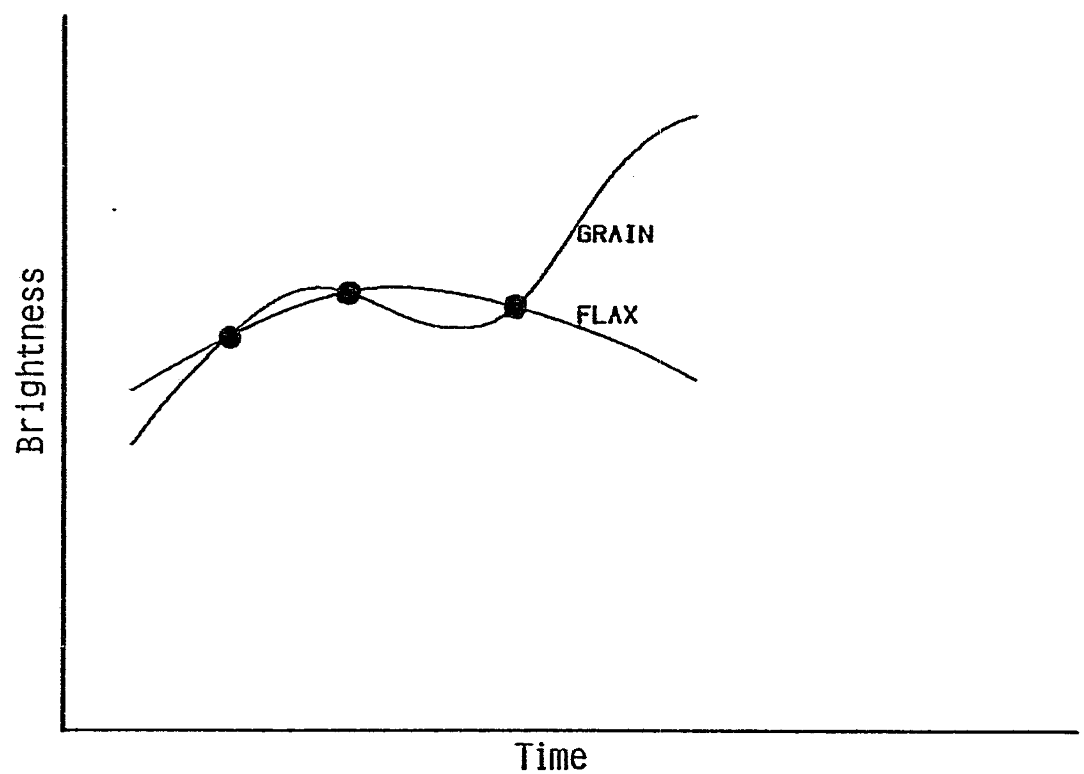


TEST AND EVALUATION RESULTS

Qualitative Component Evaluation

Profiles and Profile-Fitting (Continued)

- Spacing of Acquisitions Relative Both to Each Other and to the Growing Season is Critical to Accurate Crop Discrimination



CONCLUSIONS

- Use of Temporal-Spectral Patterns of Development and Spectrally-Based Information Related to Planting and Development Stage Can, with Minimal Analyst Resources, Provide Moderately Good Labeling Accuracies

- A Technology Based Only on Greenness Profiles is Probably Not Going to be Sufficient

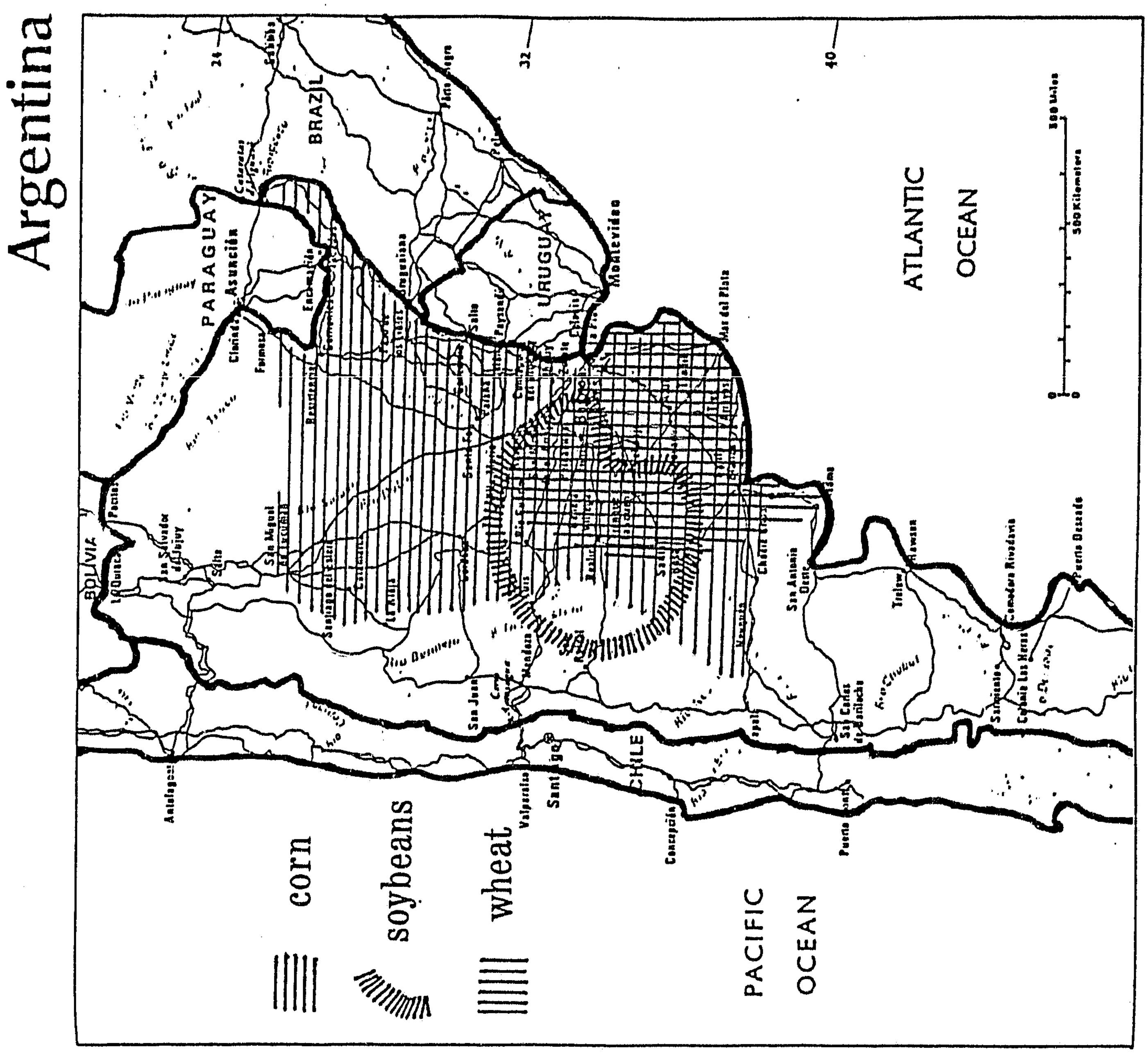
- An Enhanced Ability to Detect the Grass/Passture Class Would Significantly Improve Overall Labeling Accuracy

  - Analyst screening of labels
  - Machine utilization of other features (e.g., field size, shape, texture)

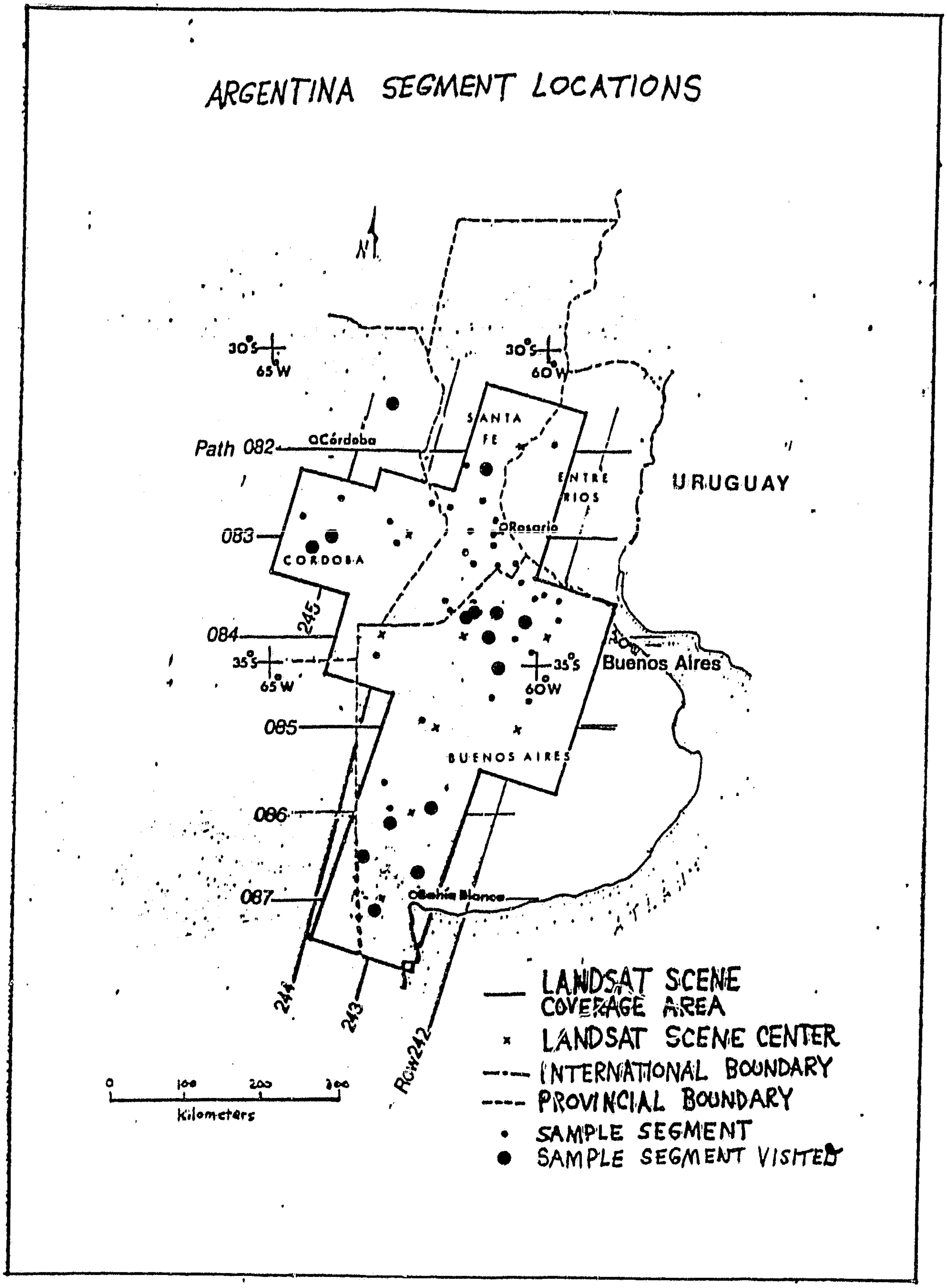
ARGENTINA DATA COLLECTION

Retrospective Schedule

- December 1980 - Implementation planning identifies critical data need/lack
- 2 January 1981 - ERIM/UCB commit to current-year field expedition
- 15 January 1981 - USDA (C. Candill, ESCS; J. Olmes, OICD) supports intent and need; offers assistance
- 21 January 1981 - OICD cables assistance request to FAS attache in Buenos Aires
- 27 January 1981 - ERIM/UCB submit collection plan to NASA
- 10 February 1981 - NASA approves trip
  - OICD indicates receipt of enthusiastic response from Argentina
- 15 February 1981 - ERIM/UCB team arrives in Buenos Aires
- 1 March 1981 - ERIM/UCB departs Buenos Aires for home


Argentina
corn
soybeans
wheat
BOLIVIA
PARAGUAY
BRAZIL
URUGUAY
CHILE
Asunción
Montevideo
Mar del Plata
Santiago
Valparaíso
Antofagasta
Concepción
ATLANTIC
OCEAN
PACIFIC
OCEAN
24
32
40

ORIGINAL PAGE IS
OF POOR QUALITY



ARGENTINA SEGMENTS INVENTORY

Segments	Province	Segment Name	Aerial Photos	Ground Truth
3	Cordoba	San Justo	Yes	Yes
		Juarez Cellman	Yes	Yes
		Rio Quarto	Yes	Yes
1	Santa Fe	San Martin	No	?
5 in South	Buenos Aires	Tornquist	No	Yes
		Puan (2)	No	Yes
		Col. Suarez	No	Yes
		Villarino	No	Yes
6 in North		Gen. Arengles (2)	No	Yes
		Junin	No	Yes
		Salto	No	Yes
		Rojas	No	Yes
		Brazado	No	Yes

U.S. Department of Agriculture
Foreign Agricultural Service
(Ag Attache - Buenos Aires - U.S. Embassy)
James Parker

Argentina Ministry of Economy
State Secretariat for Agriculture and Livestock

Director, International Agriculture Service -	Antonio T. Parsons
Deputy Director -	Julia Elena Rivarola Ezequiel Fonsela
Dept. of Ag Estimates -	Eduardo Anchubidart (Chief) *Claudio Fonda
Dept. of Natural Resources and Ecology -	*Miguel Abraham
National Technological Institute of Agriculture -	*Carlos Scopa *Nestor Darwich
National Commission for Space Investigations -	J. J. Tosso *Cecilia Espoz Eugenio Ernesto Portalet

*We had closest contact with these people (field work).

ORIGINAL PAGE IS OF POOR QUALITY

REPORTING ORG./ACTIVITY: ARGENTINA AND BRAZIL AGRONOMIC UNDERSTANDING

DATE 2/10/81

PAGE

ACTIVITY	FY1981 (O N D J F M A M J J A S)	FY1982 (O N D J F M A M J J A S)
REFERENCE MILESTONES		
DEFINE, COLLECT & ORGANIZE FOREIGN UNDERSTANDING DATA BASE		
NOAA (weather & climate)	PRELIMINARY ▽; FINAL ▽	REPORT ▽
USDA	▽	
NASA	ARGENTINA SEGMENTS ▽; ▽ BRAZIL SEGMENTS	
OTHER		
FOREIGN GROUND TRUTH DATA COLLECTION	TRIP PLAN ▽; ▽ ARGENTINA FIELD TRIP; GT OVERLAY ▽; ▽ REPORT	TRIP PLAN ▽; ▽ BRAZIL & ARGENTINA FIELD TRIP; GT OVERLAYS ▽; ▽ REPORT
PREPARE COUNTRY SPECIFIC REPORTS		
ARGENTINA	CROP CAL's ▽; ▽ STATISTICS & AG. CHAR; ▽ REPORT	
BRAZIL	GENERAL ▽; ▽ CROP CAL; ▽ STATISTICS & AG. CHARACTERISTICS	▽ REPORT; ▽ AG & ENVIRON. CHARACTERIZATION
SUPPORT TO NASA ON COOPERATIVE AGREEMENT & GROUND TRUTH DATA COLLECTION	BRAZIL (INPE) ▽; ▽ ARGENTINA	ARGENTINA (TENTATIVE)
OUTPUT PRODUCT MILESTONES		

CORN AND SOYBEAN

CLASSIFICATION TECHNOLOGY DEVELOPMENT

FOR AREA ESTIMATION

for

FOREIGN COMMODITY PRODUCTION FORECASTING

Environmental Research Institute of Michigan
University of California at Berkeley

FCPF Quarterly Project Review

11 March 1981

C/S CLASSIFICATION TECHNOLOGY DEVELOPMENT

FCPF Objectives

- Conduct Foreign Exploratory Experiments in Classification Technology for Corn and Soybeans in Support of Pilot Experiments
- Deliver Pilot-Compatible C/S Classification Procedures
- Support Pilots
- Support Technology Transfer to User

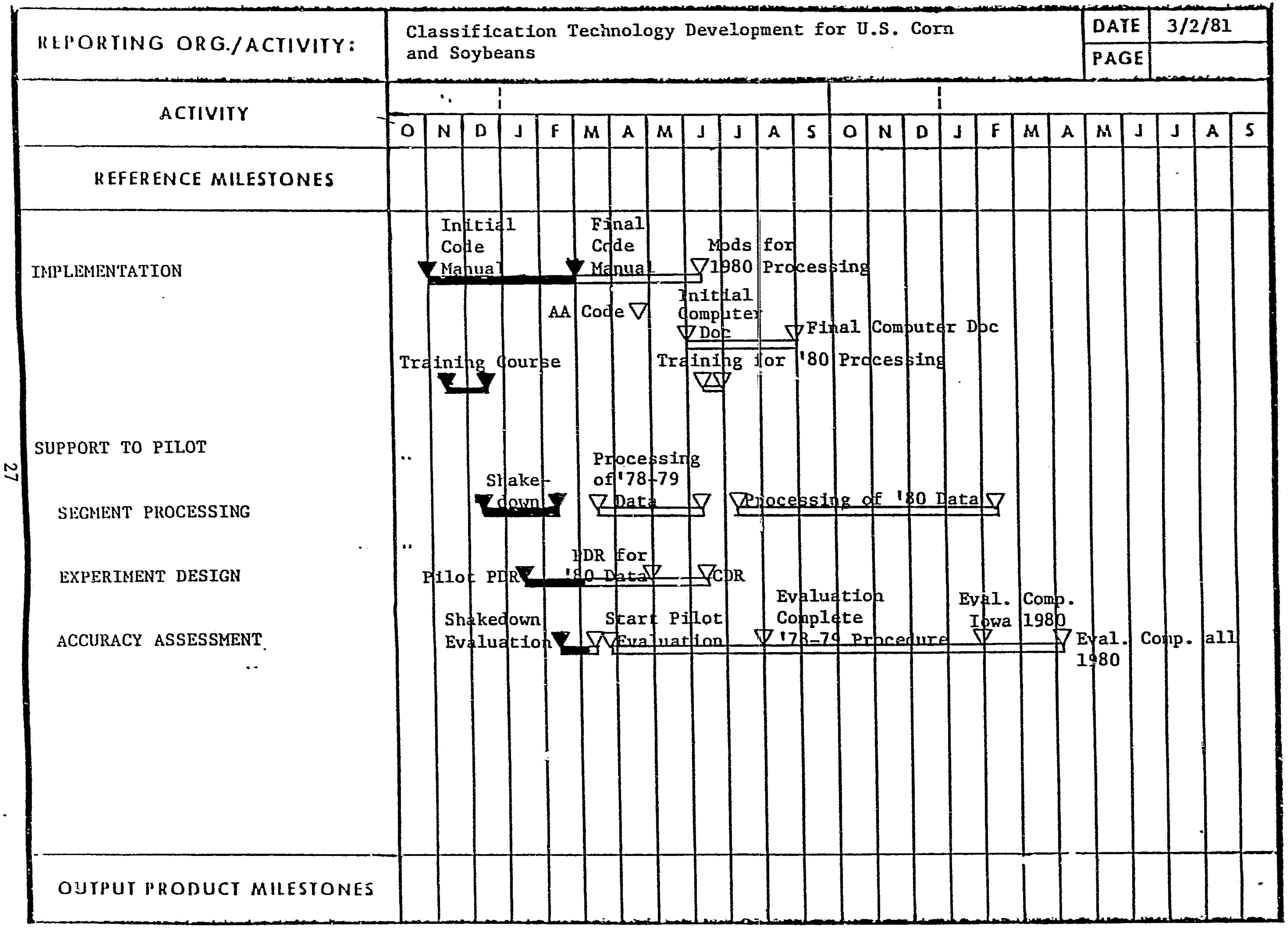
TECHNOLOGY PHASE I

U.S. C/S CLASSIFICATION TECHNOLOGY DEVELOPMENT

TECHNICAL OBJECTIVE

- DEVELOP AND IMPLEMENT BASELINE SEGMENT CLASSIFICATION PROCEDURE FOR AT-HARVEST ESTIMATES SUITABLE FOR APPLICATION IN THE U.S. CORN BELT

ORIGINAL PAGE IS
OF POOR QUALITY



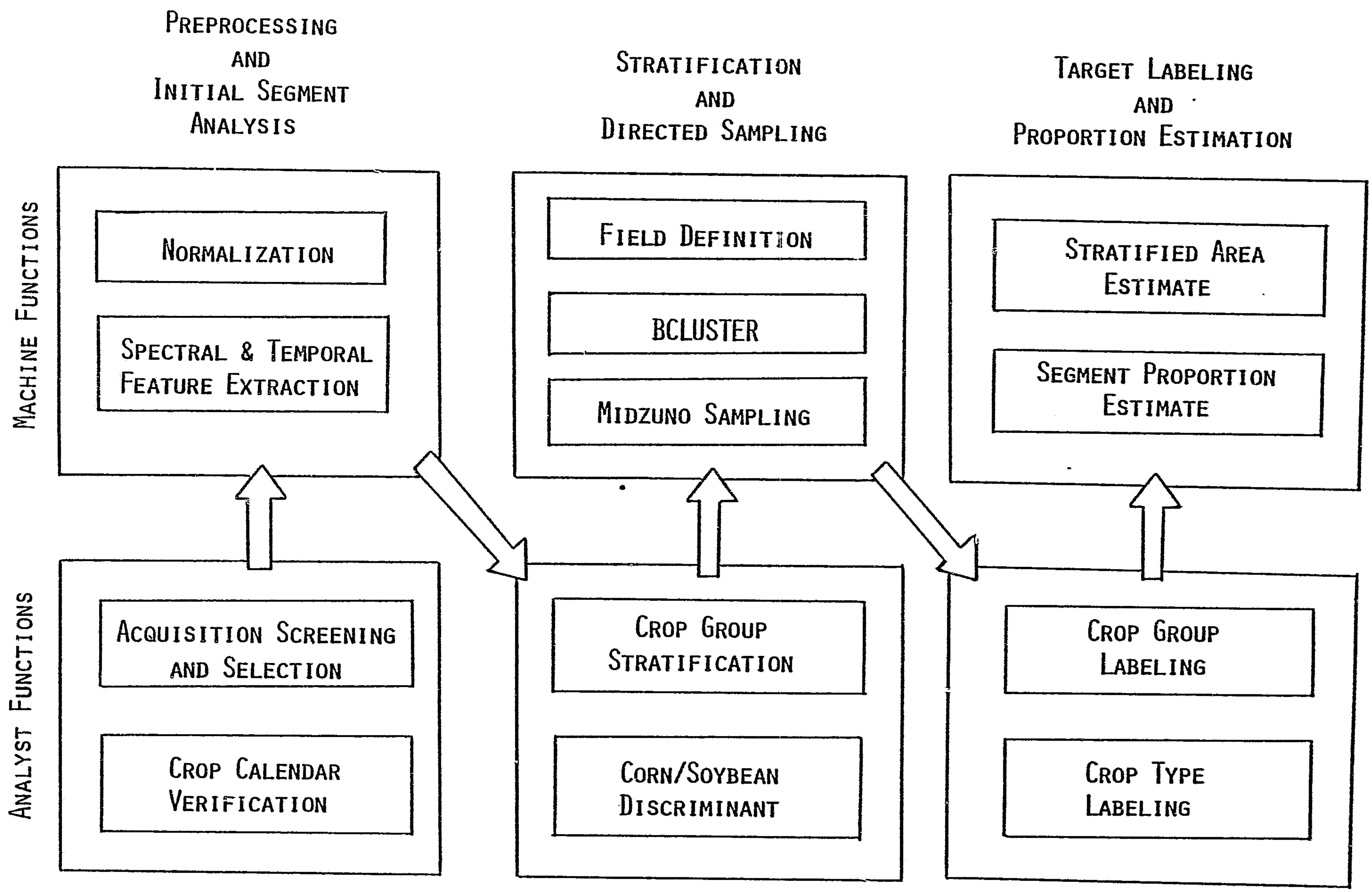
FY81 U.S. C/S PILOT IMPLEMENTATION APPROACH

- OVERALL IMPLEMENTATION MANAGED BY ERIM
- ANALYST FUNCTIONS INTEGRATED BY UCB
- SOFTWARE DEVELOPMENT ON LARS COMPUTER PENDING AVAILABILITY OF ERSYS AT JSC
- EXISTING TECHNOLOGY MODIFIED AND IMPLEMENTED
  - PROCEDURE M TUNED FOR CORN/SOYBEANS
  - JSC LABELING PROCEDURE ADAPTED TO FIELD-LIKE TARGETS RATHER THAN DOTS
  - CROP GROUP STRATIFICATION INTEGRATING
    - ANALYST
    - CROP CALENDARS
    - MACHINE

KEY ELEMENTS OF END-TO-END PROCEDURE DESIGN

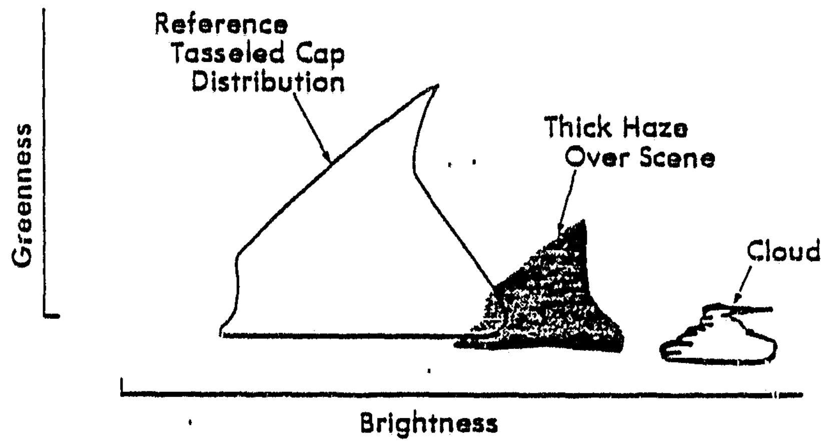
- Integrated Analyst and Machine Functions
- Crop Calendars Formally Integrated
- Preprocessing for Data Normalization and Feature Extraction
- Analyst Labeling of Field Like Targets
- Convergence of Evidence Labeling Logic
- Stratified Area Estimation
- Modular Component Structure

CORN/SOYBEAN BASELINE SEGMENT CLASSIFICATION PROCEDURE

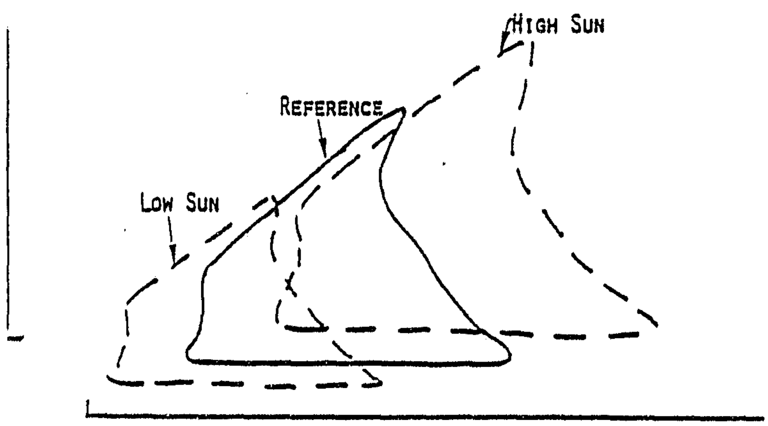


ORIGINAL PAGE IS
OF POOR QUALITY

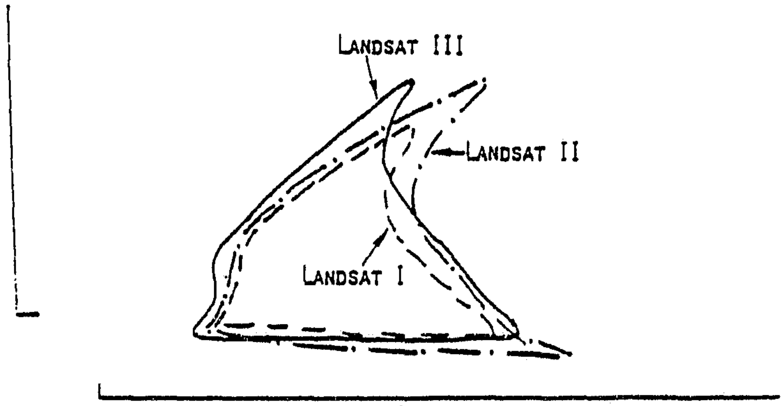
NORMALIZATION



ATMOSPHERIC CORRECTION

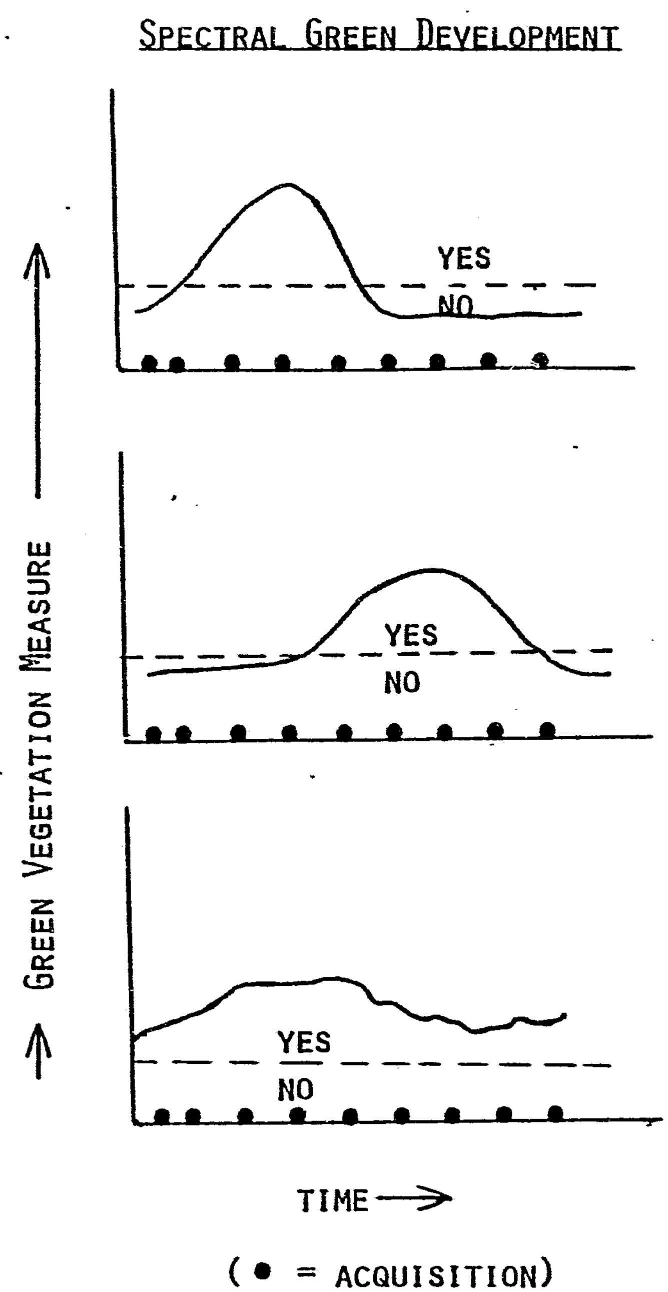


SUN ANGLE CORRECTION



SENSOR CALIBRATION

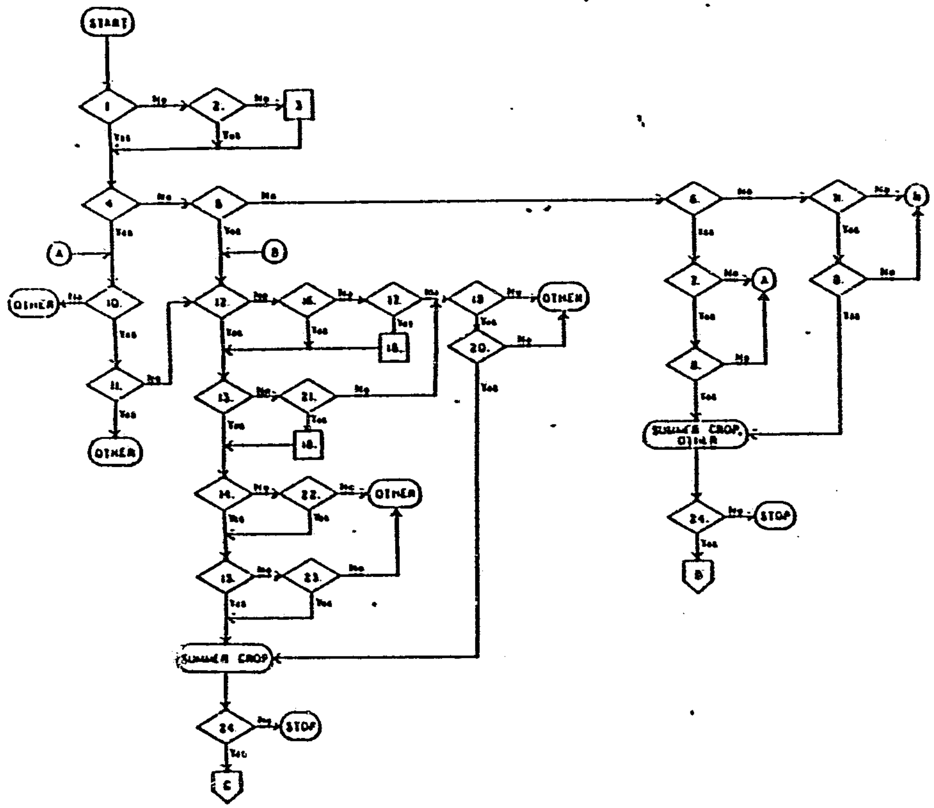
TEMPORAL VEGETATIVE DEVELOPMENT



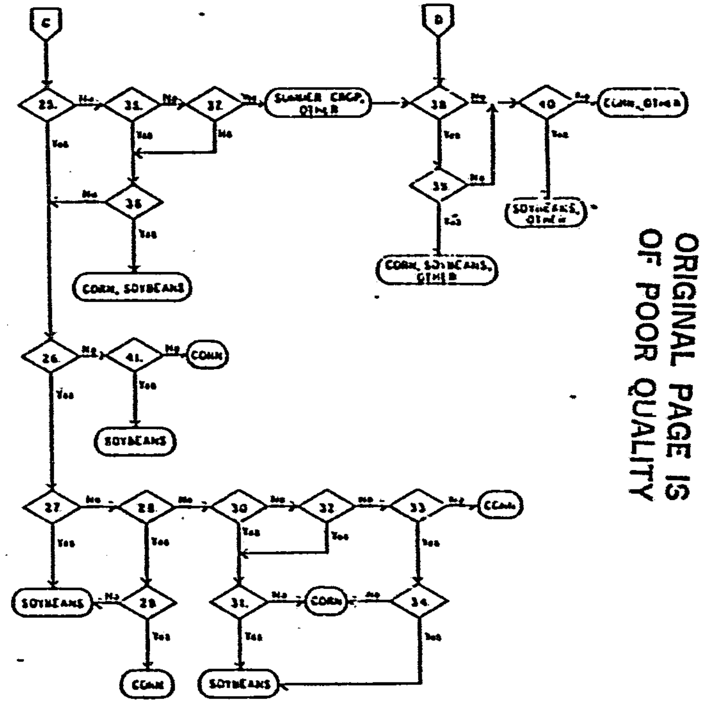
	TEMPORAL SEQUENCE (TPC)
SPRING GRAIN	0 0 1 1 1 0 0 0 0
SUMMER CROP	0 0 0 0 1 1 1 1 0
PASTURE	1 1 1 1 1 1 1 1 1

DECISION LOGIC

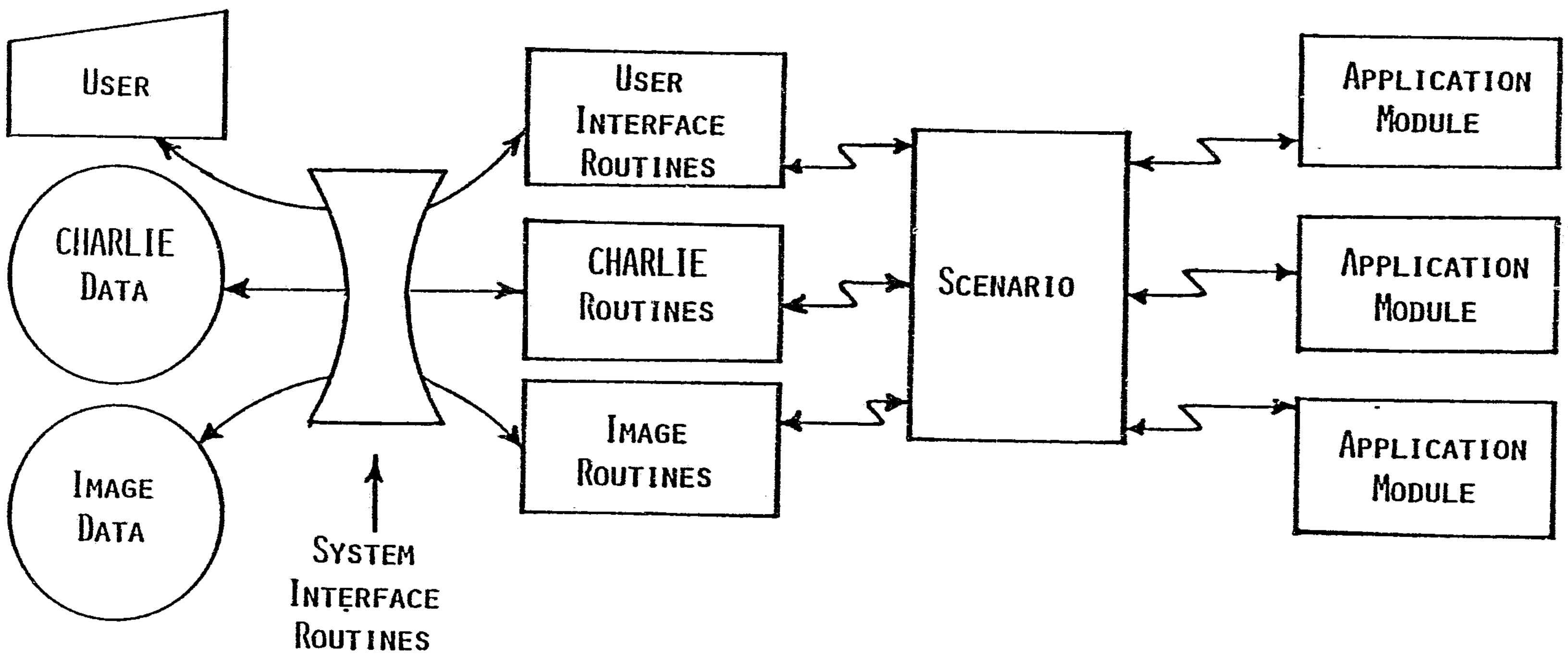
Crop Group Decision Logic



Crop Type Decision Logic



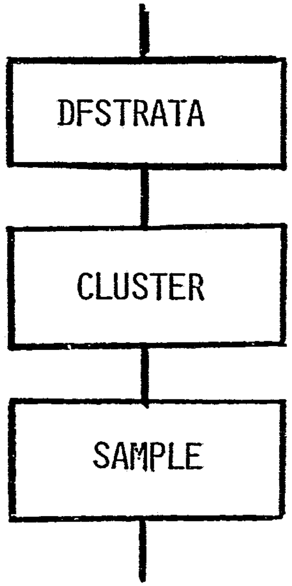
SYSTEM ORGANIZATION

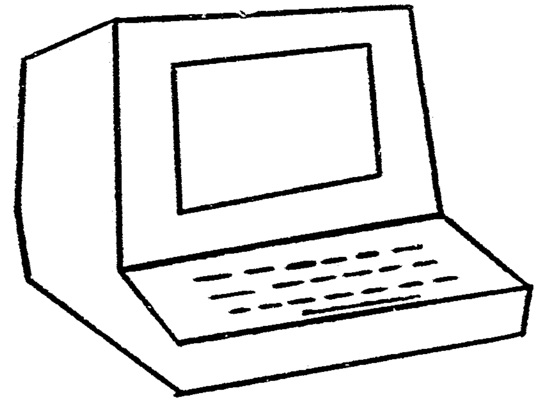


ERIM

USER LANGUAGE

- DATAPREP
- PREPROCESS
- DFS
- CLUSTER
- SAMPLE
- ESTIMATE
- CLEAR
- ASK





CLUSTER

Enter Segment Name

Segment 844

Enter Acquisition Dates in the Form yyddd

78151, 78232, 78251

ACCURACY ASSESSMENT SOFTWARE

- Blob Labels from Ground Truth
- "Correct" Spectral Biowindows from Ground Truth and GRABS
- Iterate BCLUSTER, SAMPLE, and ESTIMATE with Varying Numbers of Clusters and Samples
- Proportion Estimates from Ground Truth

QUALITY ASSURANCE

- Analyst Decisions for 5-10% of the Segments Processed Will be Examined
- Several (5) of the Segments Processed Will be Independently Processed by ERIM/UCB Personnel

MODIFICATIONS FOR PHASE II

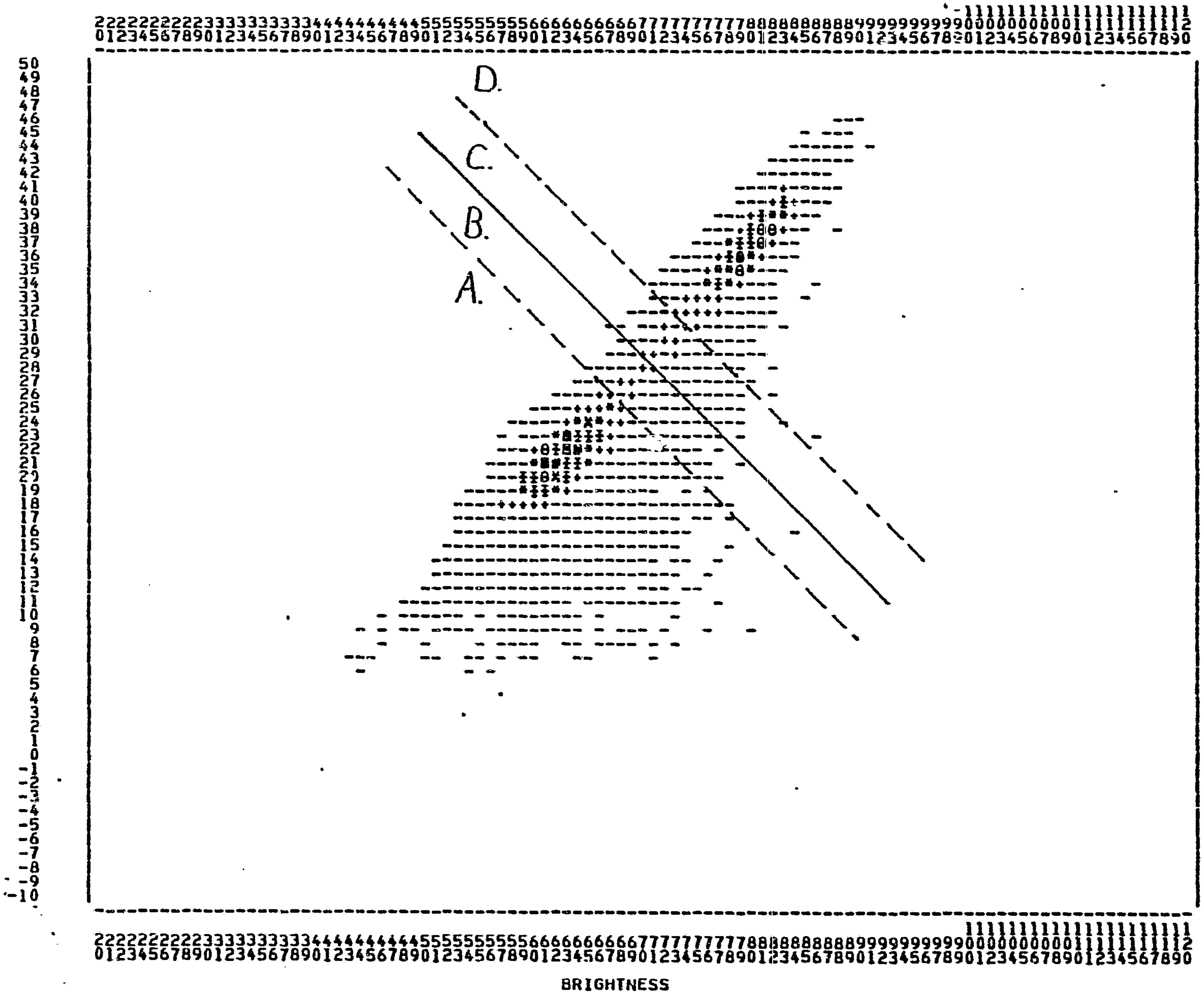
- Is Analyst Team Needed?
- Do Queuing Problems Exist?
- Can Procedure be Further Automated?
  - DFS assignment
  - Placement of linear discriminant

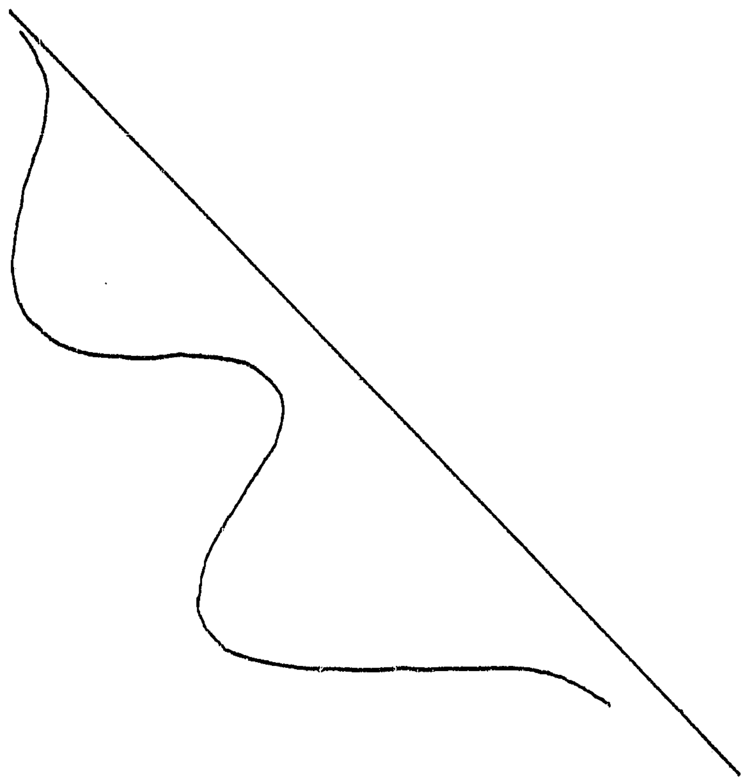
ORIGINAL PAGE IS
OF POOR QUALITY

S C A T T E R   P L O T
SEGMENT NAME: 88282
STRATUM: 1 "PURE SUMMER"
SUBWINDOW: 1,117,1,1,196,1

PREPARED ON: 15105112 02-06-81
ACQUISITION: 78231
TOTAL PIXELS:
NOT IN STRATUM: 2292

OUTSIDE SUBSCENE:
NUMBER PLOTTED: 20640
NOT IN PLOT AREA:





ANALYST CONTACT TIME

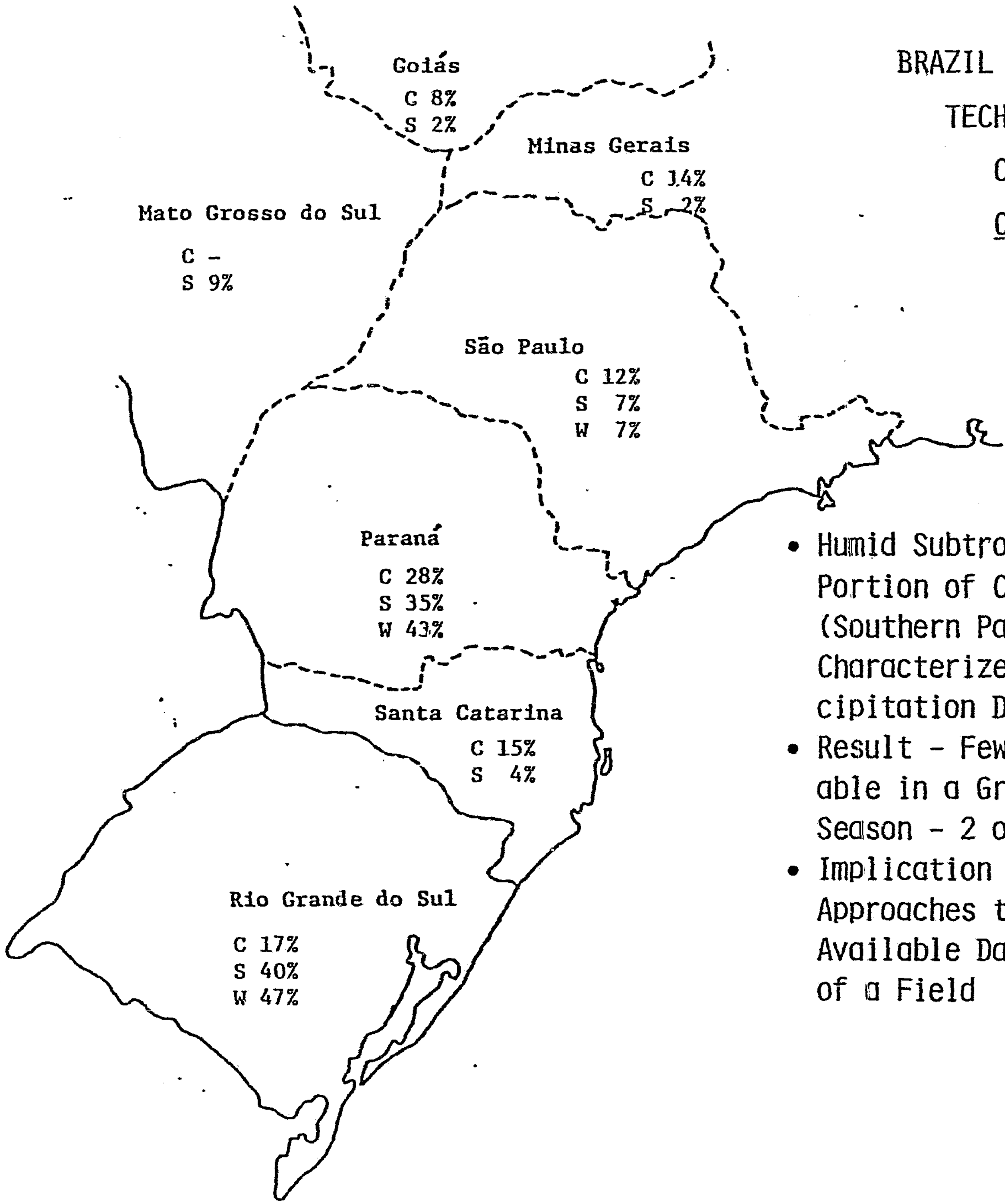
FUNCTION	TIME (minutes)	ANALYSTS
Gain familiarity with segment	60	2
Adjust Crop calendar	120	2
Choose acquisitions	40	2
Determine Expected TPCs	30	2
QA, fill out forms	10	2
Assign TPC's to DFS	45	2
Execute DFS	10	2
Execute SCATTER	120	2
Find linear discriminants	15	2
Select blob acquisitions	10	2
Paper work	10	2
Make crop biowindow overlay	10	1
Labeling	600	1
Quality Assurance	120	1

BRAZIL CORN AND SOYBEANS

TECHNOLOGY PHASE

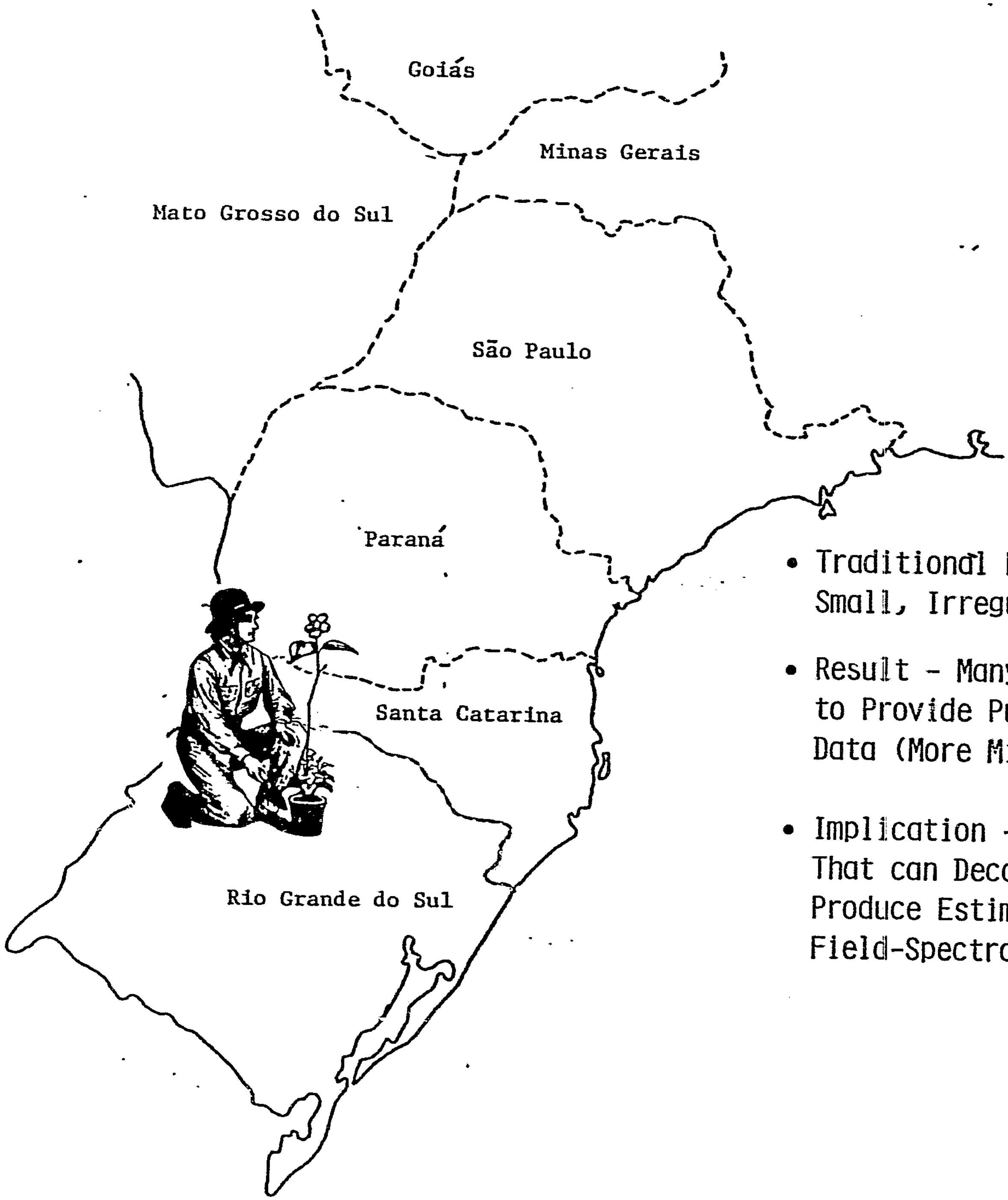
CHALLENGES

<u>Cloud Cover</u>



- Humid Subtropical Climate in Southern Portion of Corn/Soy Producing Region (Southern Paraná and Southward) is Characterized by Fairly Uniform Precipitation Distrbution
- Result - Few Good Acquisitions Available in a Growing Season (1979-80 Season - 2 or Less Good Quarter Frames)
- Implication - Need to Develop New Approaches to Labeling that Use all Available Data to Infer the Crop Type of a Field

BRAZIL CORN AND SOYBEAN
TECHNOLOGY PHASE
CHALLENGES
Field Cover



- Traditional Farmers Tend to Plant in Small, Irregularly-Shaped Fields
- Result - Many Fields Will be too Small to Provide Pure Signatures in Landsat Data (More Mixture Pixels)
- Implication - Techniques are Required That can Decompose Mixed Signatures or Produce Estimates Without Requiring Field-Spectral Labels

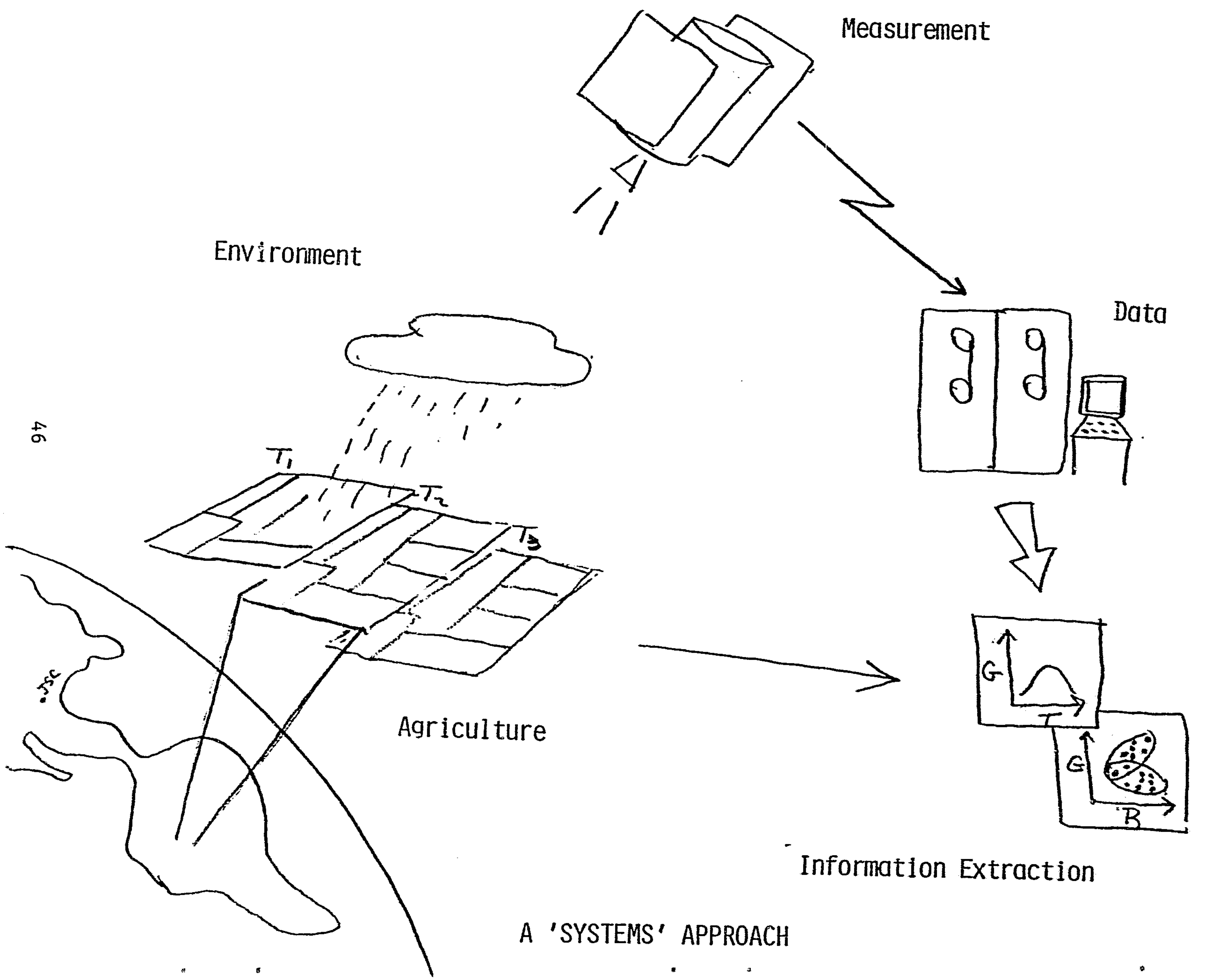
OVERVIEW of CORN / SOYBEANS PATTERN RECOGNITION

Technical Issues

Quarterly Technical Interchange

23 march 1981

R. Cicone



A 'SYSTEMS' APPROACH

ENVIRONMENTAL SYSTEM

General	Specific
Weather - cloud cover - moisture - temperature - episodic events	Impact of Cloud Cover on South America Acquisition Profile
Geomorphology	External Effects Correction (esp. TM) (seperating internal and external effects manifested in features)
Insects and Disease	Crop / Weather interaction

MEASUREMENT SYSTEM

General

Dynamic Range X Scene of Interest

Noise Characteristics

Measurement Parameters
- frequency
- viewing geometry
- IFOV
- radiometric characteristics

Specific

MSS maintainance
- impact of deterioration
- calibration

Thamatic Mapper Characteristics
- data rate
- incremental gain over MSS
- data structure
- response to external effects

Potential Use of Multiple Sensors

DATA SYSTEMS

General	Specific
Data Base	Continued Augmentation of Image Data Base
Data System	Foreign Ground Truth
	Potential of Interactive Analysis
	Image Processing System

INFORMATION EXTRACTION SYSTEM

General	Specific
Information Content	
feature space	agronomic features
crop space	stable features
information need	labeling / estimation methodology
extraction methodology	
Accuracy	
crop inseparability	summer crop confusors (e.g.corn,sorghum)
estimation performance	impact of mixed pixels
	bias in classifiers
	stability of dirct estimators
Efficiency	
rate of error	multisegment / regression aggregation
processing intensity	streamlining
	self assessment
Timeliness	
periodic & timely information	through - the - season methods
early as possible	Landsat alone inadequate
	multiyear potential

'TALL POLES' AMONG TECHNICAL ISSUES IN CORN/SOYBEAN PATTERN RECOGNITION RESEARCH

- o DATA (IMAGE DATA CONTINUITY, FOREIGN GROUND DATA AND HISTORICAL/AGRONONIC/MIX DATA)
- o THROUGH-THE-SEASON TECHNOLOGY (WITH EXPLORATION OF LANDSAT ANGMINTED ECONOMETRIC APPROACHES)
- o PARCTICABLE PROCEDURES AT A COUNTRY LEVEL (I.E. REDUCTION OF PROCESSING INTENSITY)
- o REDUCTION OF BIAS AND VARIANCE CHARACTERISTICS ASSOCIATED WITH CORRENT LABELING, SAMPLING AND ESTIMATION TECHNOLOGICS
- o THOROUGH UNDERSTANDING OF CROP CHARACTERISTICS AND THEIR REMOTE SENSING MANIFESTATIONS
- o DETERMINATION OF PARAMETERS THAT DRIVE DIRECTIONAL CHANGES WITHIN THE DATA STRUCTURE WE OBSERVE
- o CONFRONTING A NEW SET OF 'CONFUSION CROPS' (E.G. CORN AND SORGHUM)
- o UNDERSTANDING AGROPHYSICAL ENVIRONMENT OF BRAZIL AND ARGENTINA AND ADAPTING TECHNOLOY TO IT

CHALLENGE OF CORN / SOYBEANS PATTERN RECOGNITION RESEARCH

Challenge lies in both confronting remote sensing issues on a generic level and delving into the specific detail of crop and country parameters to produce a viable technology

SMALL FIELDS RESEARCH

W. Holsztynski

H. Horwitz

F. Pont

Environmental Research Institute of Michigan

Quarterly Technical Interchange Meeting

March 23-26, 1981

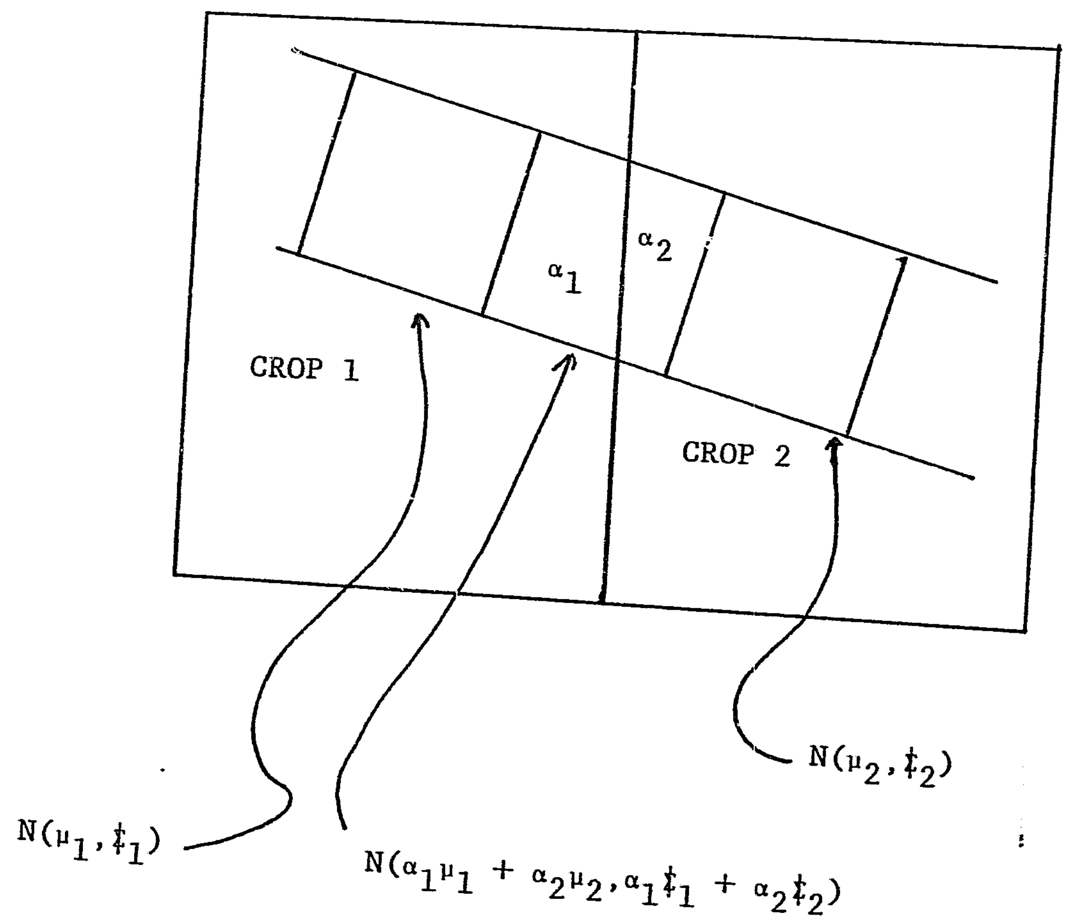
OBJECTIVES OF SMALL FIELDS RESEARCH

- Short Range
  - Gain understanding of small fields phenomena
    - Interaction between ground and sensor space geometries
    - Impact of small fields on crop signatures
    - Impact of field size on existing technologies (Blob, CLASSY, etc.)
- Longer Range
  - Support the development of small fields procedures

APPROACH

- Define Small Field as a Field Which Contains No Pure Pixels
- Use a Series of Fixed Field Patterns and Vary Pixel Size (As Pixel Size Increases, Number of Small Fields Increases)
- Uses Several Field Patterns
  - Simulated
  - Landsat
  - Ground truth polygons
- Uses Crop Profiles Obtained from Real Data

MODEL FOR FIXED PIXEL



- Model for Fixed Pixel Time t

  (No Misregistration)

  $$N(\sum \alpha_i \mu_i(t),\ \Sigma \alpha_i \ddagger_i(t))$$

- Model for Fixed Pixel

  (Misregistration)

  $$N(\Sigma \alpha_i(t) \mu_i(t),\ \Sigma \alpha_i(t) \ddagger_i(t))$$

- Model for a Randomly Selected Pixel

  (No Misregistration)

  $$N(\Sigma A_i \mu_i(t),\ \Sigma A_i \ddagger_i(t))$$

  where A_i is a random mixing coefficient

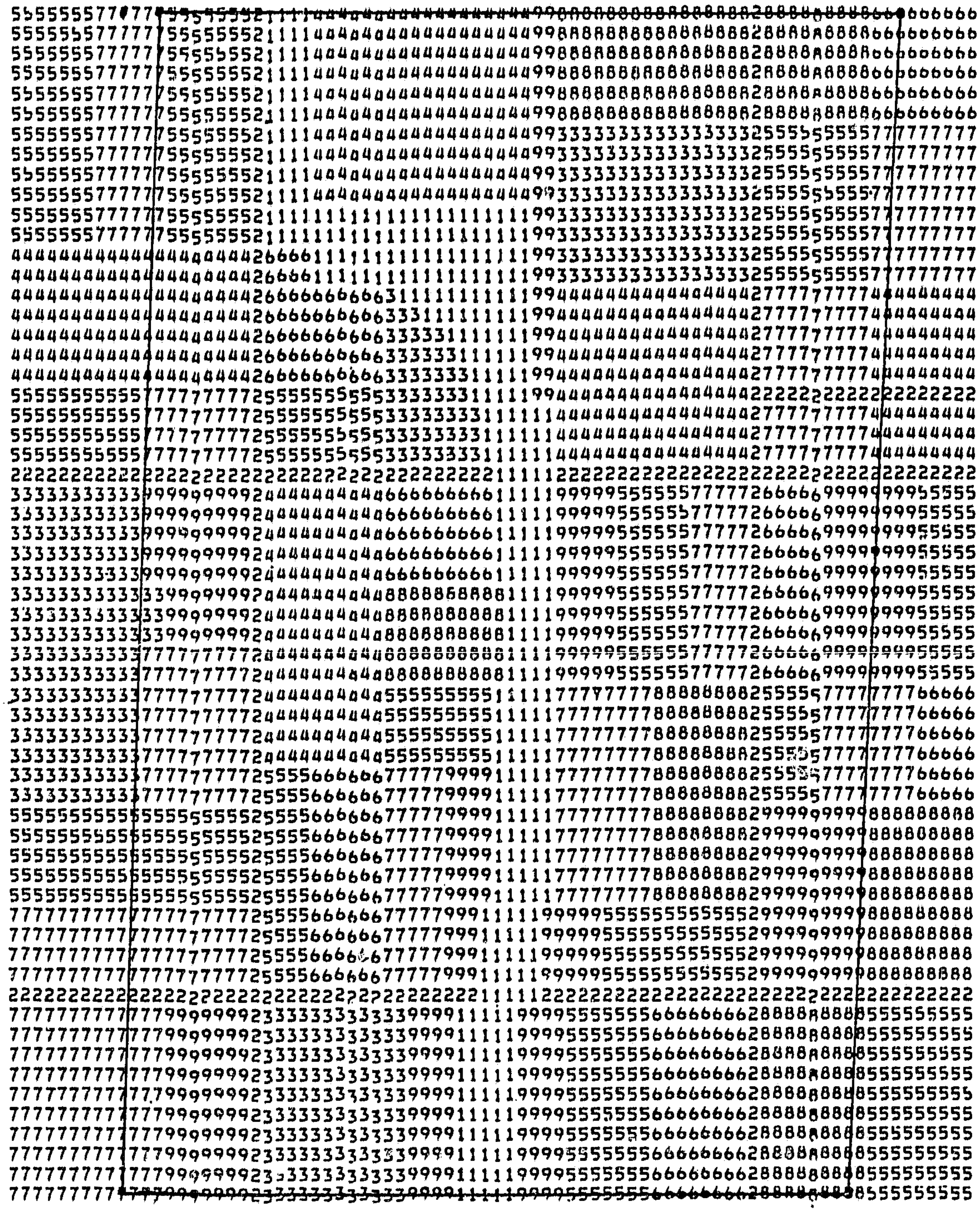
  $$(\Sigma A_i = 1 \ \text{ and } \ A_i \geq 0)$$

- Model for a Randomly Selected Pixel

  (Misregistration)

  $$N(\Sigma A_i(t) \mu_i(t),\ \Sigma A_i(t) \ddagger_i(t))$$

ORIGINAL PAGE IS
OF POOR QUALITY



1. Water
2. Road
3. Late Soybeans
4. Early Soybeans
5. Late Corn
6. Early Corn
7. Late Grain
8. Early Grain
9. Grass

Days 160, 178, 196, 214

NAME OF THE GROUNDFIELD: FAKE-FIELD-14
9 CROPS; VERTICES (70, 1), (73, 60), (13, 60), (10, 1)
40 COLUMNS AND 40 ROWS

PURE PIXELS

```
8 8 8   5 5 5 5 5 7 7 7 2 7 7   9 9 9 9 9 9 7 7 7 7             2 5 5 5 5 5 5 5
8 8 8   5 5 5 5 5 7 7 7 2 7 7   9 9 9 9 9 9 7 7 7 7 9 9 9 9 9 9 2 8 8 8 8 8 8 8
8 8 8   5 5 5 5 5 7 7 7 2 7 7             9 7 7 7 7 9 9 9 9 9 9 2 8 8 8 8 8 8 8
8 8 8   5 5 5 5 5 7 7 7 2 7 7   6 6 6 6 6 6 5 5 5 5 9 9 9 9 9 9 2 8 8 8 8 8 8 8
8 8 8   5 5 5 5 5 7 7 7 2 7 7   6 6 6 6 6 6 5 5 5 5 9 9 9 9 9 9 2 8 8 8 8 8 8 8
      2 2 2 2 2 2       2       6 6 6 6 6 6 5 5 5 5 9 9 9 9 9 9 2 8 8 8 8 8 8 8
8 8 8   3 3 3 3 3 4 4 4 4 4 4                 2 2 2 2 2 2       2       8 8 8 8
8 8 8   3 3 3 3 3 4 4 4 4 4 4   7 7 7 7 7 7 8 8 8 8 8 8 8   5 5 2 6 6 6
8 8 8   3 3 3 3 3 4 4 4 4 4 4   7 7 7 7 7 7 8 8 8 8 8 8 8   5 5 2 6 6 6 6 6 6 6
8 8 8   3 3 3 3 3 4 4 4 4 4 4       7 7 7 7 8 8 8 8 8 8 8   5 5 2 6 6 6 6 6 6 6
8 8 8   3 3 3 3 3 4 4 4 4 4 4   5 5 5 5 5 5 8 8 8 8 8 8 8   5 5 2 6 6 6 6 6 6 6
8 8 8   3 3 3 3 3 4 4 4 4 4 4   5 5 5 5 5 5 8 8 8 8 8 8 8   5 5 2 6 6 6 6 6 6 6
8 8 8   3 3 3 3 3 4 4 4 4 4 4   5 5 5 5 5 5 7 7 7 7 7 7 7   5 5 2             6
8 8 8   3 3 3 3 3 4 4 4 4 4 4           5 5 7 7 7 7 7 7 7   5 5 2 5 5 5 5 5 5 5
8 8 8   3 3 3 3 3 4 4 4 4 4 4   9 9 9 9 9 9 7 7 7 7 7 7 7   5 5 2 5 5 5 5 5 5 5
8 8 8   3 3 3 3 3 4 4 4 4 4 4   9 9 9 9 9 9 7 7 7 7 7 7 7   9 9 2 5 5 5 5 5 5 5
9 9 9 9 9 9 9 9                 9 9 9 9 9 9 7 7 7 7 7 7 7   9 9 2 5 5 5 5 5 5 5
4 4               9 9 9 9 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1     9 9 2 9 9 9 9 9 9 9
4 4 4 4 4 4 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 9 9 9 9 9 9 9
4 4 4 4 4 4 1 1 1 1 1 1 1 1 1 1 1 1 1       1 1 1 1 1 1 1 1 1 1 1       9 9 9 9
4 4 4 4 4 4 1 1 1 1 1 1 1       6 6 6 8 8 8 5               1 1 1 1 1 1 1 1 1 1
4 4 4 4 4 4 1 1 1 1 1   3 3 3   6 6 6 8 8 8 5 5 5 9 9 9 9 9       1 1 1 1 1 1 1
4 4 4 4 4 4 1 1 1 1 3 3 3 3 3   6 6 6 8 8 8 5 5 5 9 9 9 9 9 9 9 2 1 1 1 1 1 1 1
4 4 4 4 4 4 1 1 1   3 3 3 3 3   6 6 6 8 8 8 5 5 5 7 7 7 7 7 7   2 9 9 9 9 9 9 9
4 4 4 4 4 4 1 1 1   3 3 3 3 3   6 6 6 8 8 8 5 5 5 7 7 7 7 7 7 7 2 9 9 9 9 9 9 9
4 4 4 4 4 4 1 1 1         3 3   6 6 6 8 8 8 5 5 5 7 7 7 7 7 7 7 2             9
4 4 4 4 4 4 1 1 1 6 6 6 5 5 5   4 4 4 4 4 4 4 4 4 6             2 3 3 3 3 3 3 3
4 4 4 4 4 4 1 1 1 6 6 6 5 5 5   4 4 4 4 4 4 4 4 4 6 6 6 6 6 6 6 2 3 3 3 3 3 3 3
4 4 4 4 4 4 1 1 1 6 6 6 5 5 5   4 4 4 4 4 4 4 4 4 6 6 6 6 6 6 6 2 3 3 3 3 3 3 3
1 1 1 1 1 1 1     6 6 6 5 5 5   4 4 4 4 4 4 4 4 4 6 6 6 6 6 6 6 2 3 3 3 3 3 3 3
1 1 1 1 1 1 1   6 6 6 6 5 5 5   4 4 4 4 4 4 4 4 4 5 5 5         2 3 3 3 3 3 3 3
      1 1 1 1   6 6 6 6 5 5 5   4 4 4 4 4 4 4 4 4 5 5 5 5 5 5 5 2 3 3 3 3 3 3 3
5 5 5               2 2 2 2 2 2               4 4 5 5 5 5 5 5 5 2 3 3 3 3 3 3 3
5 5 5 5 5 5 5   4 4 4 4 7 7 7   9 9 9 9 9 7 7               2 2 2 2 2 2
5 5 5 5 5 5 5   4 4 4 4 7 7 7   9 9 9 9 9 7 7 7 7 7 5 5 5   7 7 2 9 9 9 9 9 9 9
5 5 5 5 5 5 5   4 4 4 4 7 7 7   9 9 9 9 9 7 7 7 7 7 5 5 5   7 7 2 9 9 9 9 9 9 9
5 5 5 5 5 5 5   4 4 4 4 7 7 7   9 9 9 9 9 7 7 7 7 7 5 5 5   7 7 2 9 9 9 9 9 9 9
7 7 7 7 7 7 7   4 4 4 4 7 7 7   9 9 9 9 9 7 7 7 7 7 5 5 5   7 7 2 9 9 9 9 9 9 9
7 7 7 7 7 7 7   4 4 4 4   7 7   9 9 9 3 3 7 7 7 7 7 5 5 5   7 7 2             9
7 7 7 7 7 7 7   4 4 4 4 5 5 5   3 3 3 3 3 3 3 3 3 3 5 5 5   7 7 2 7 7 7 7 7 7 7
```

```
NAME OF THE GROUNDFIELD: FAKE-FIELD-14
        9 CROPS,          VERTICES ( 70,  1), ( 73, 60), ( 13, 60), ( 10,  1)
       30  COLUMNS   AND    30  ROWS
```

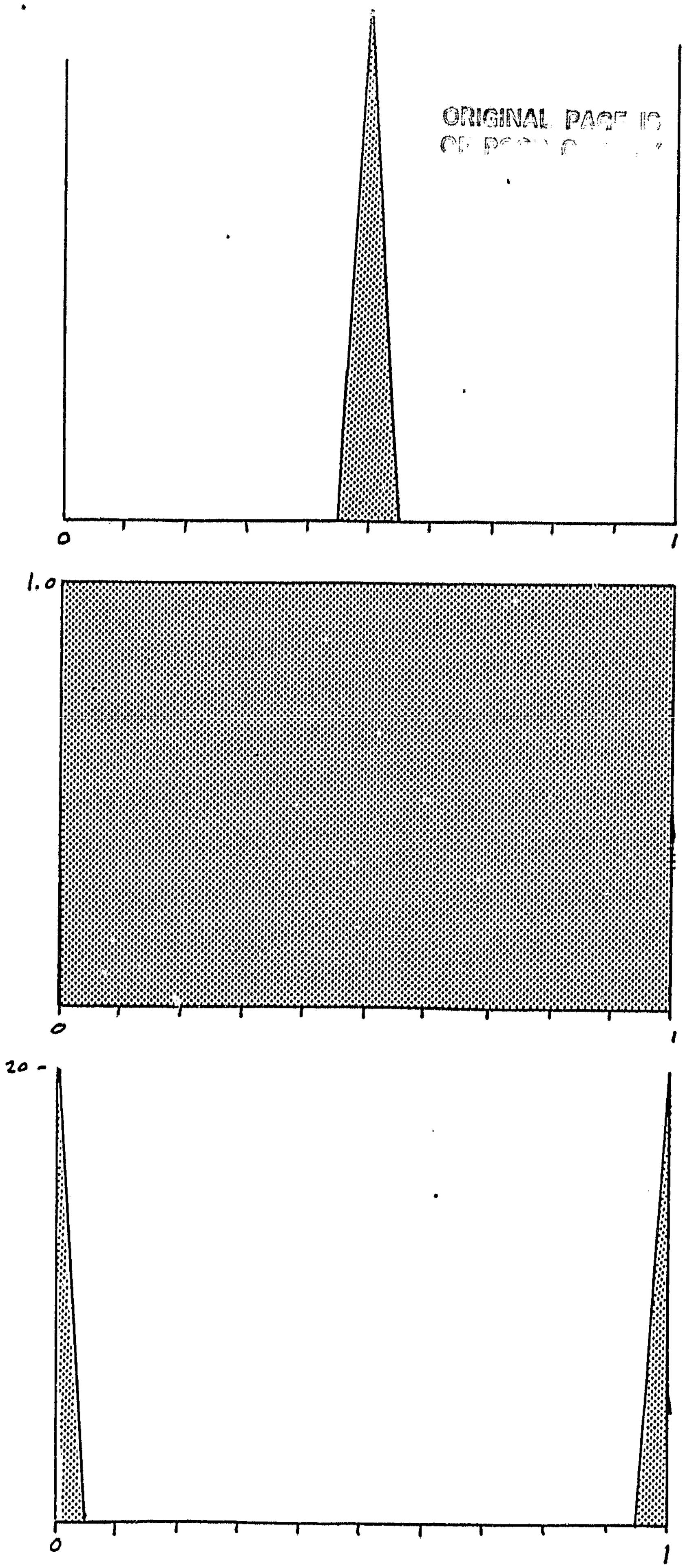
PURE PIXELS

8	8		5	5	5		7	7		7		9	9	9	9		7	7											
8	8		5	5	5		7	7		7		9	9	9	9		7	7		9	9	9	9		8	8	8	8	8
8	8		5	5	5		7	7		7		6	6	6	6		5	5		9	9	9	9		8	8	8	8	8
			5	5	5		7	7		7		6	6	6	6		5	5		9	9	9	9		8	8	8	8	8
8	8																						9		8	8	8	8	8
8	8		3	3	3		4	4	4	4		7	7	7	7		8	8	8	8	8	5							
8	8		3	3	3		4	4	4	4		7	7	7	7		8	8	8	8	8	5	5		6	6	6	6	6
8	8		3	3	3		4	4	4	4		5	5				8	8	8	8	8	5	5		6	6	6	6	6
8	8		3	3	3		4	4	4	4		5	5	5	5		8	8	8	8	8	5	5		6	6	6	6	6
8	8		3	3	3		4	4	4	4		5	5	5	5		7	7	7	7	7	5	5						
8	8		3	3	3		4	4	4	4		9	9	9	9		7	7	7	7	7	5	5		5	5	5	5	5
8	8		3	3	3		4	4	4	4		9	9	9	9		7	7	7	7	7	9	9		5	5	5	5	5
9	9	9	9	9	9	9	9												7	7	7	9	9					5	5
4	4	4	4		1	1	1			1	1	1	1	1	1	1	1	1	1	1	1				9	9	9	9	9
4	4	4	4		1	1	1	1	1	1	1	1	1				1	1	1	1	1	1	1						
4	4	4	4		1	1	1					6	6	8	8		5		9			1	1	1	1	1	1	1	1
4	4	4	4		1	1		3	3	3		6	6	8	8		5		9	9	9	9	9		1	1	1	1	1
4	4	4	4		1	1		3	3	3		6	6	8	8		5		7	7					9	9	9	9	9
4	4	4	4		1		3	3	3	3		6	6	8	8		5		7	7	7	7	7		9	9	9	9	9
4	4	4	4		1		6	6	5	5													7		3	3	3	3	3
4	4	4	4		1		6	6	5	5		4	4	4	4	4	4		6	6	6	6	6		3	3	3	3	3
					1		6	6	5	5		4	4	4	4	4	4		6	6	6	6	6		3	3	3	3	3
1	1	1	1	1		6	6	6	5	5		4	4	4	4	4	4								3	3	3	3	3
						6	6	6	5	5		4	4	4	4	4	4		5	5	5	5	5		3	3	3	3	3
5	5	5	5	5																							3	3	3
5	5	5	5	5		4	4	4	7	7		9	9	9		7	7	7		5	5	7	7		9				
5	5	5	5	5		4	4	4	7	7		9	9	9		7	7	7		5	5	7	7		9	9	9	9	9
						4	4	4	7	7		9	9	9		7	7	7		5	5	7	7		9	9	9	9	9
7	7	7	7	7		4	4	4		7		9	9	3		7	7	7		5	5	7	7						9
7	7	7	7	7		4	4	4	5	5		3	3	3	3	3	3	3		5	5	7	7		7	7	7	7	7

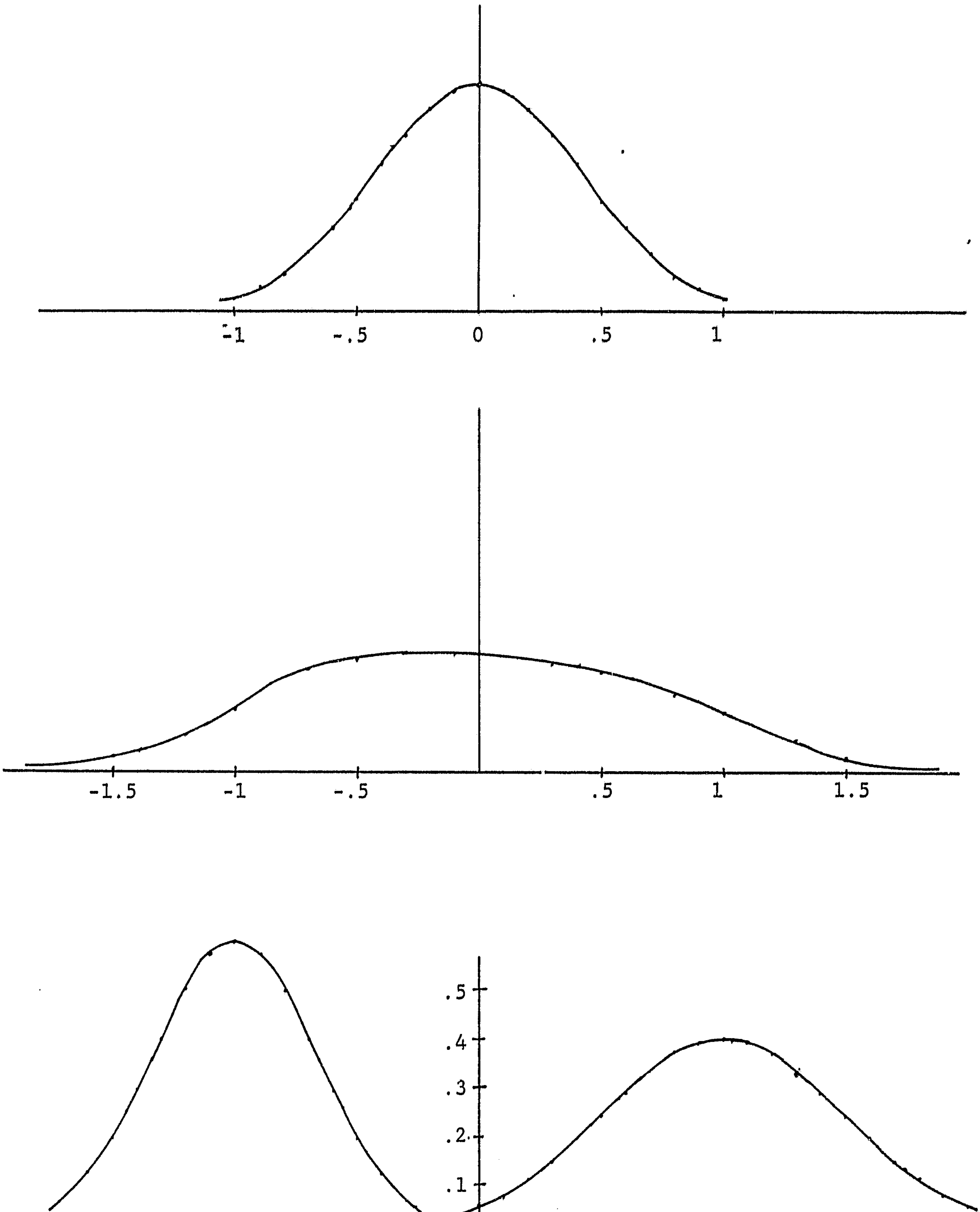
ORIGINAL PAGE IS
OF POOR QUALITY

```
NAME OF THE GROUNDFIELD: FAKE-FIELD-14
        9 CROPS,          VERTICES ( 70,  1), ( 73, 60), ( 13, 60), ( 10,  1)
       20  COLUMNS    AND    20  ROWS

  PURE PIXELS

8       5   5       7           9   9       7
8       5   5       7                               9   9       8   8   8   8
                                            5       9   9       8   8   8   8
8       3   3       4   4       7
8       3   3       4   4                   8   8   8           6   6   6   6
8       3   3       4   4       5   5               8           6   6   6   6
8       3   3       4   4                   7   7   7           5   5
        3   3       4   4       9   9       7   7   7           5   5   5   5
                            1
4   4   4   1   1   1   1                   1   1   1   1   1
4   4   4   1   1               6          .5   9   9           1   1   1   1
4   4   4   1       3   3       6           5                   9
4   4   4   1                                       7   7
4   4   4   1       6   5       4   4   4   4   6   6   6       3   3   3   3
1                   6   5       4   4   4   4                   3   3   3   3
                                        4   4   5   5   5       3   3   3   3
5   5   5       4   4   7       9
5   5   5       4   4   7       9   9   7   7       5           9   9   9   9
7   7   7       4   4           9       7   7       5                       9
7   7   7       4   4   5       3   3   3   3       5           7   7   7   7
```

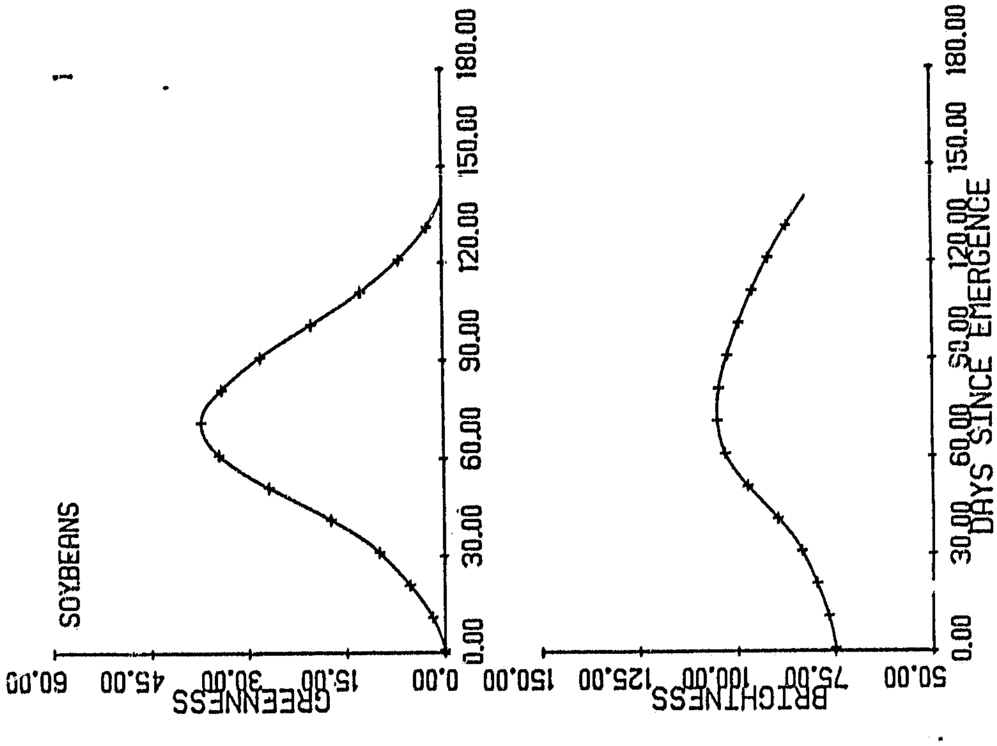
- Conditional Profile Distribution
  - $f_{X|A=\alpha}(X) \sim N(\Sigma\alpha_1\mu_1, \Sigma\alpha_i\Sigma_i)$
- Mixing Distribution
  - $f_A(\alpha)$
  - Function of:
    - •• Ground field patterns
    - •• Misregistration
    - •• Generals unknown
- Joint Mixture-Profile Distribution
  - $f_{X,A}(X,\alpha) = f_A(\alpha) f_{X|A=\alpha}(X,\alpha)$
- Marginal Distribution of X
  - $f_X(X) = \int_0^1 f_{X,A}(X,\alpha)\, d\alpha$

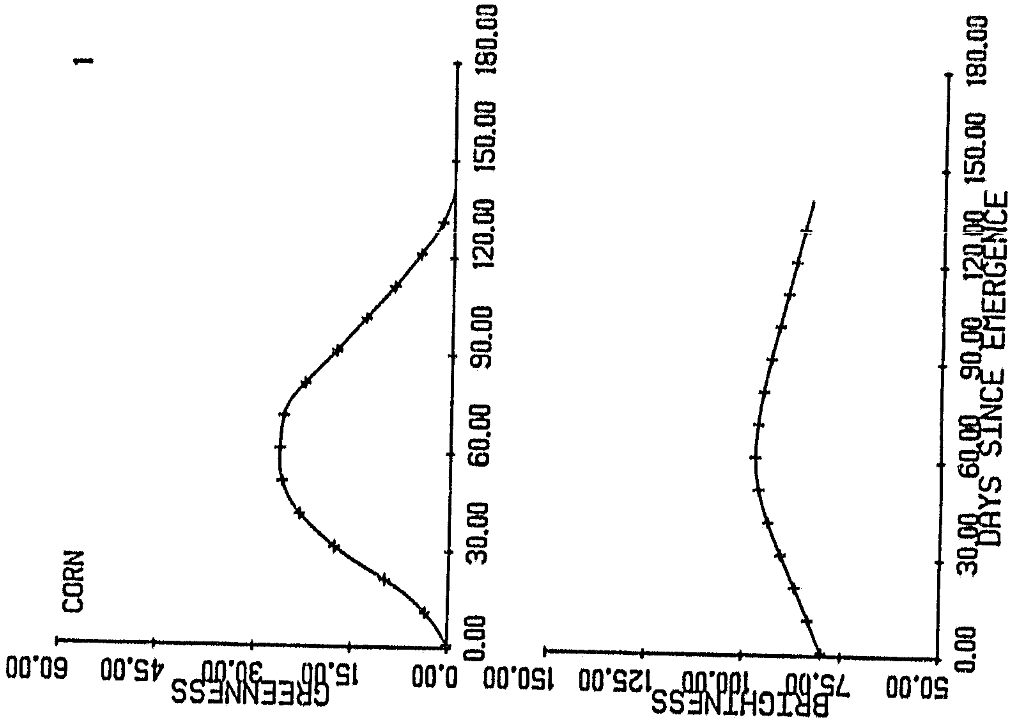


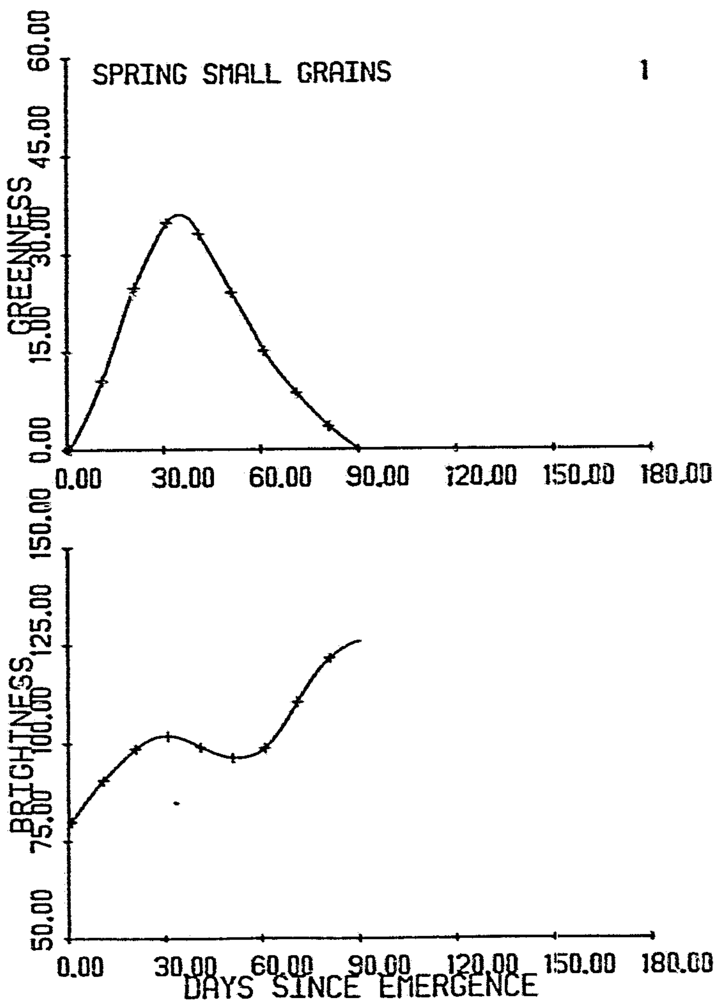
POSSIBLE 2-CROP MIXING DISTRIBUTIONS

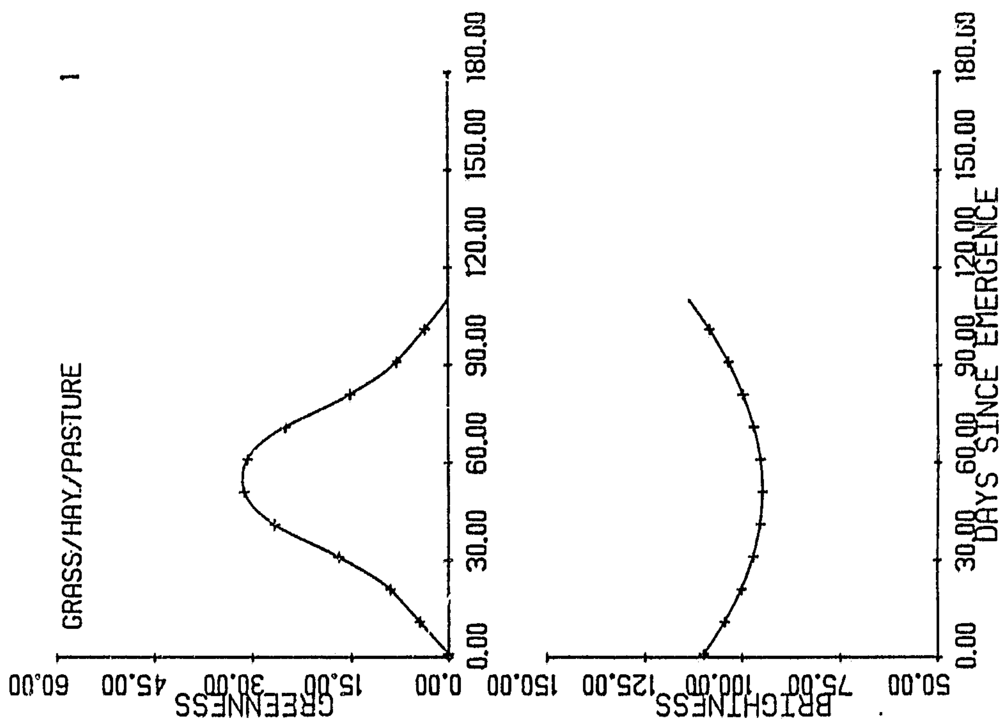


POSSIBLE 2-CROP MARGINAL DISTRIBUTION USES N(-1,1/9) AND N(1,1/4)


SOYBEANS
GREENNESS
0.00 15.00 30.00 45.00 60.00
BRIGHTNESS
50.00 75.00 100.00 125.00 150.00
DAYS SINCE EMERGENCE
0.00 30.00 60.00 90.00 120.00 150.00 180.00

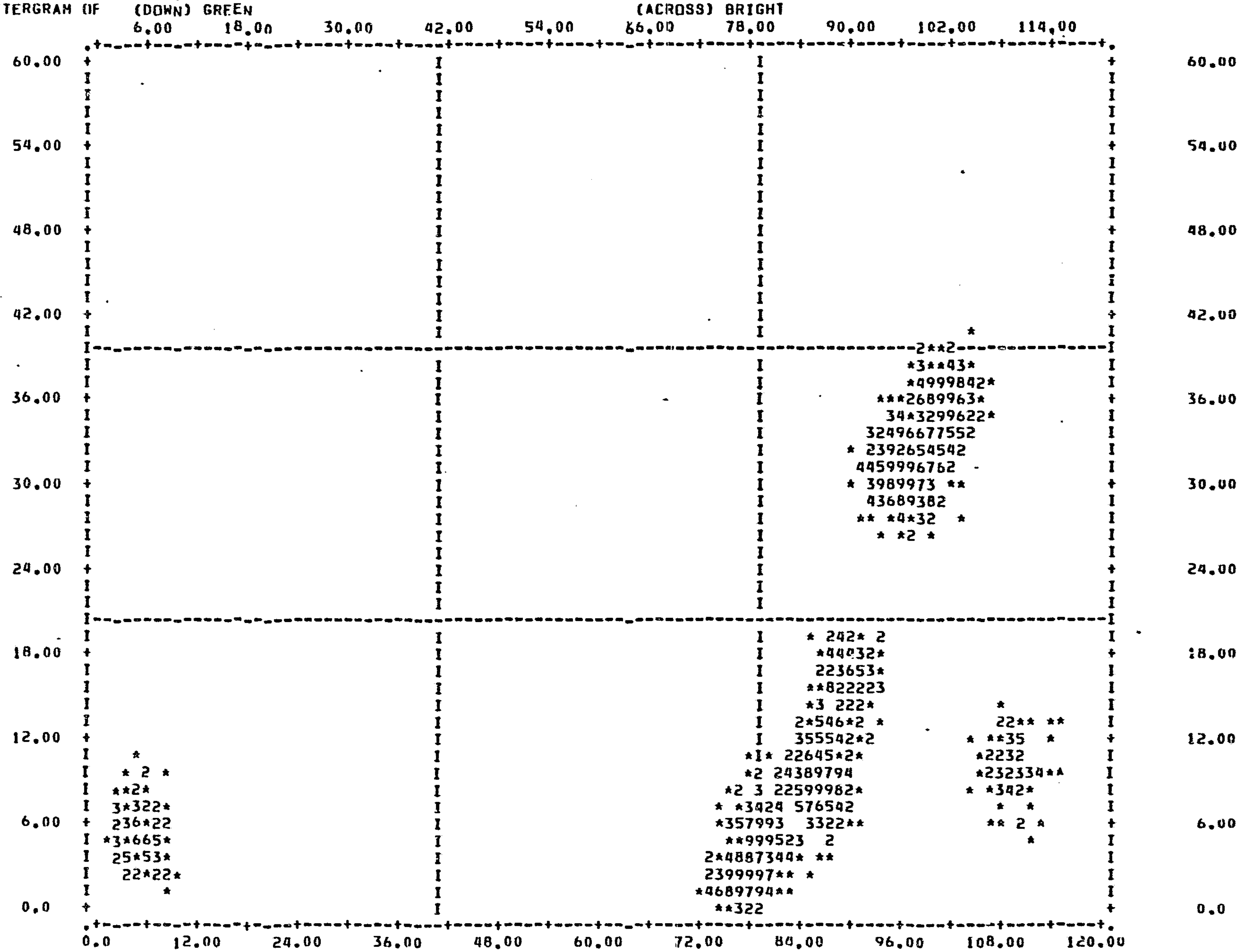

CORN
1
GREENNESS
0.00
15.00
30.00
45.00
60.00
BRIGHTNESS
50.00
75.00
100.00
125.00
150.00
0.00
30.00
60.00
90.00
120.00
150.00
180.00
DAYS SINCE EMERGENCE


SPRING SMALL GRAINS
1
GREENNESS
0.00
15.00
30.00
45.00
60.00
0.00
30.00
60.00
90.00
120.00
150.00
180.00
BRIGHTNESS
50.00
75.00
100.00
125.00
150.00
0.00
30.00
60.00
90.00
120.00
150.00
180.00
DAYS SINCE EMERGENCE


GRASS/HAY/PASTURE
1
GREENNESS
0.00
15.00
30.00
45.00
60.00
BRIGHTNESS
50.00
75.00
100.00
125.00
150.00
DAYS SINCE EMERGENCE
0.00
30.00
60.00
90.00
120.00
150.00
180.00

PATTERN-14 DAY=160 V=4.0 R=0.0 NO MISREGISTRATION PURE PIXELS 03/17/81 PAGE 3

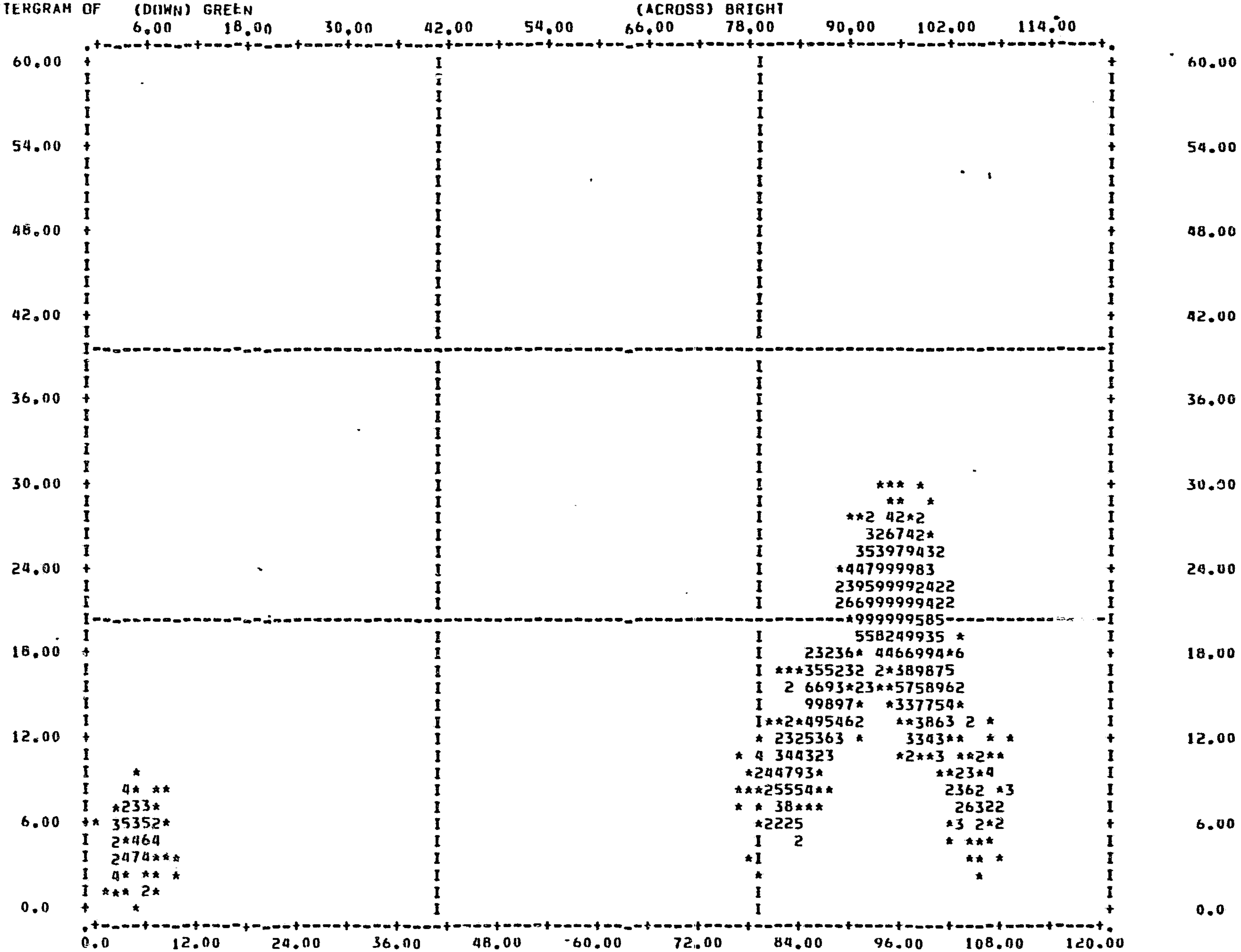
FILE NONAME (CREATION DATE = 03/17/81)
SCATTERGRAM OF (DOWN) GREEN (ACROSS) BRIGHT



ORIGINAL PAGE IS
OF POOR QUALITY

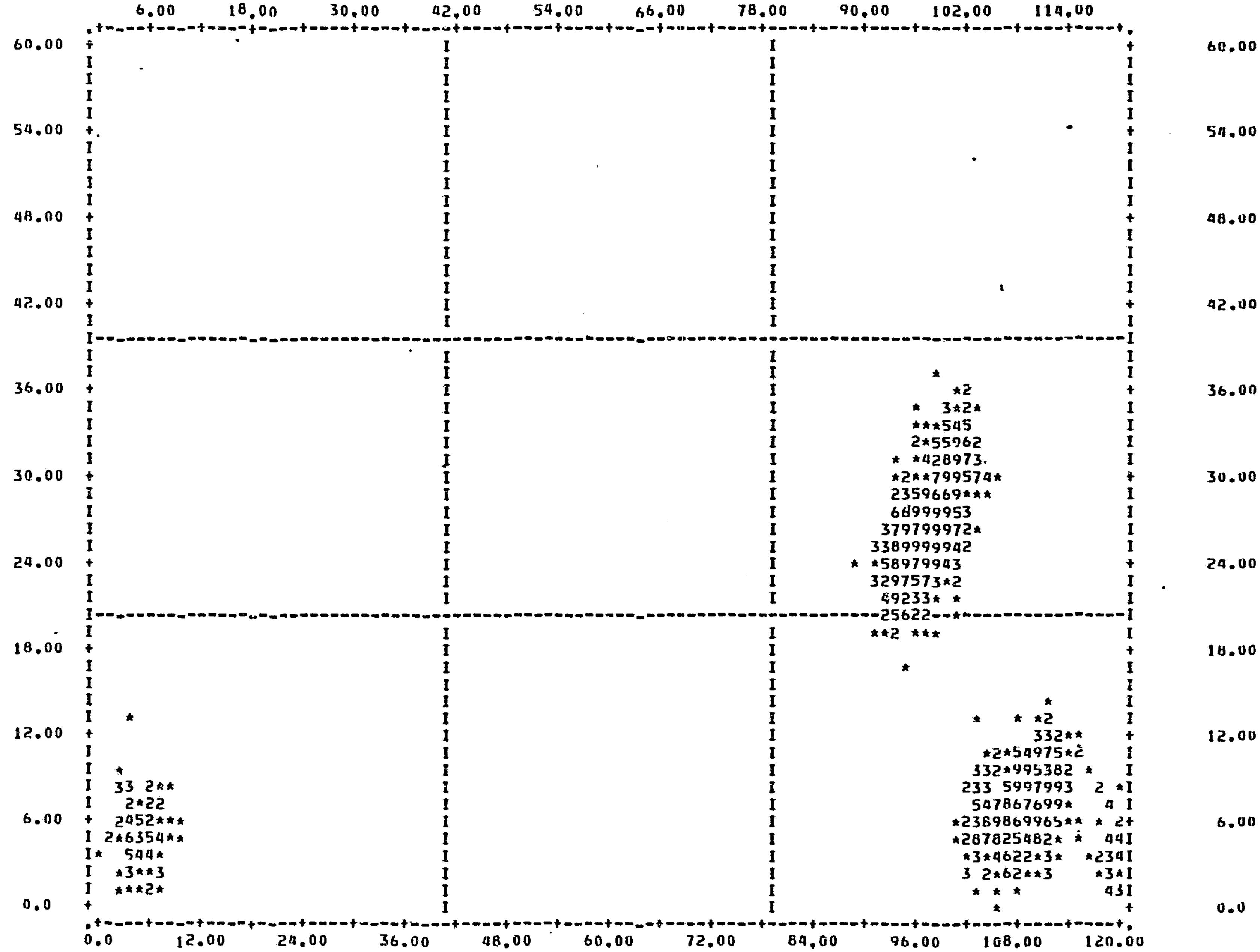
PATTERN-14 DAY=178 V=4.0 R=0.0 NO MISREGISTRATION PURE PIXELS 03/17/81 PAGE 3

FILE NONAME (CREATION DATE = 03/17/81)
SCATTERGRAM OF (DOWN) GREEN (ACROSS) BRIGHT



PATTERN-14 DAY=196 V=4.0 R=0.0 NO MISREGISTRATION PURE PIXELS 03/17/81 PAGE 3

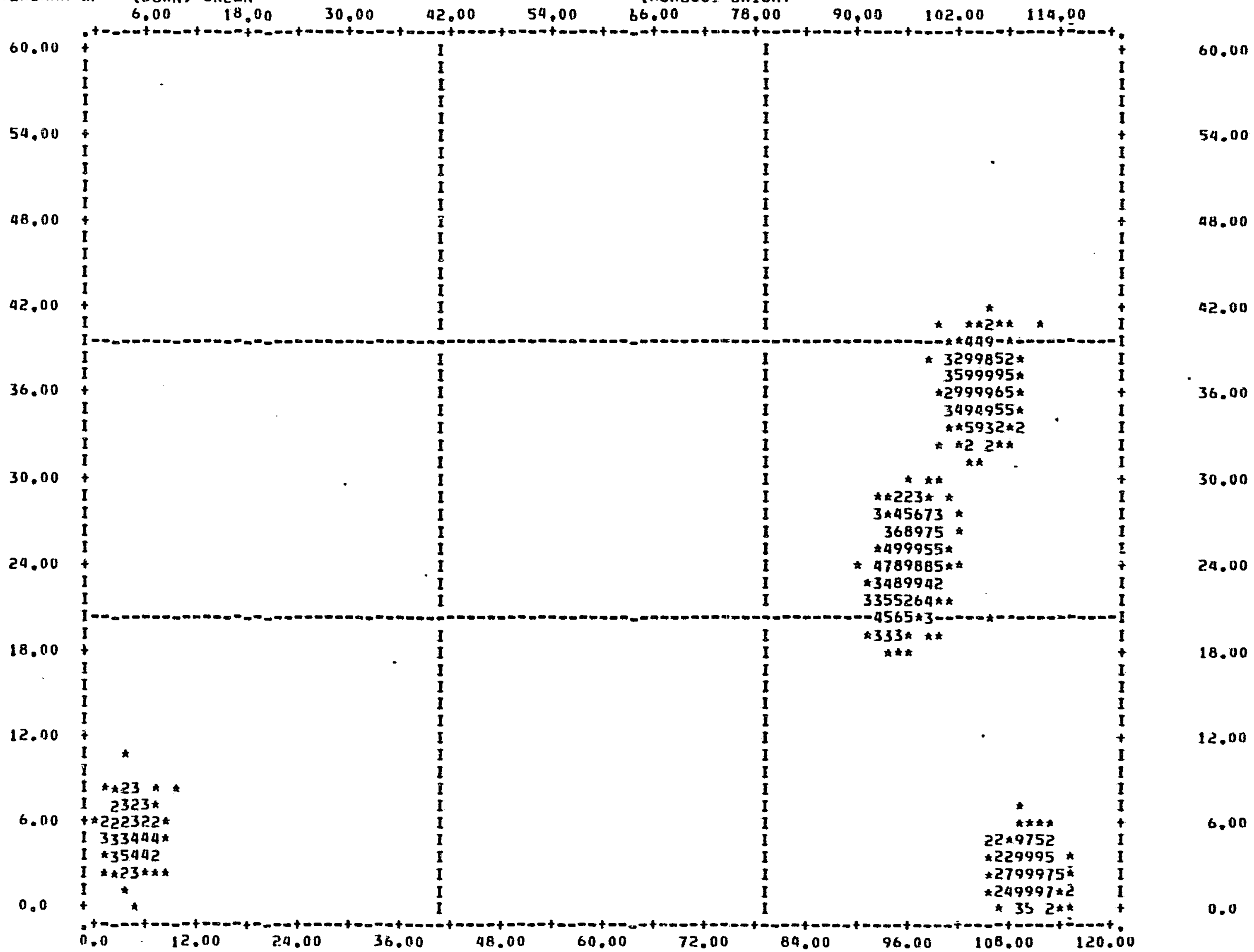
FILE NONAME (CREATION DATE = 03/17/81)
SCATTERGRAM OF (DOWN) GREEN (ACROSS) BRIGHT



ORIGINAL PAGE IS
OF POOR QUALITY

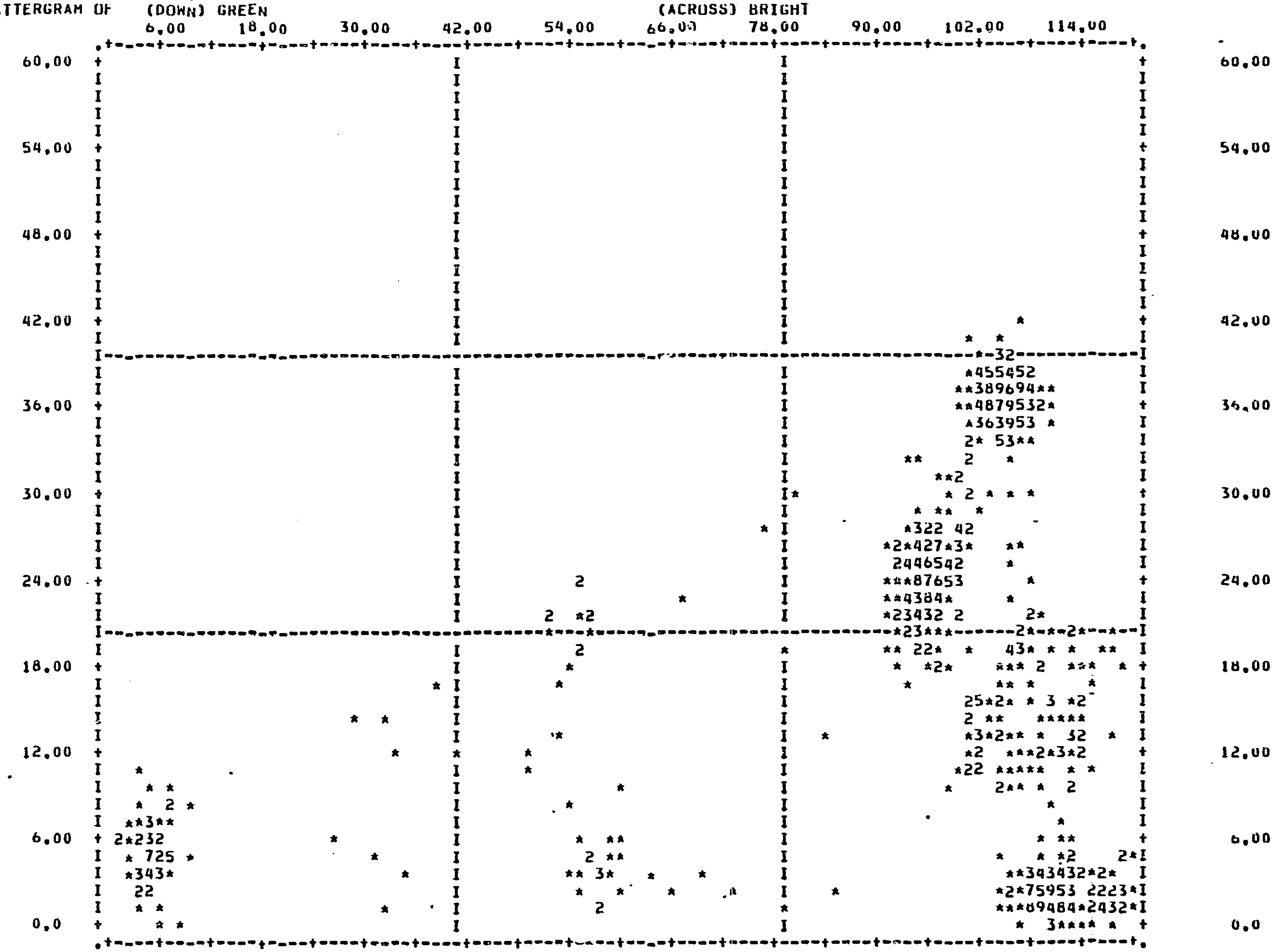
PATTERN-14 DAY=214 V=4.0 R=0.0 NO MISREGISTRATION PURE PIXELS 03/17/81 PAGE 3

FILE NONAME (CREATION DATE = 03/17/81)
SCATTERGRAM OF (DOWN) GREEN (ACROSS) BRIGHT



PATTERN-14 DAY=214 V=4.0 R=0.0 NO MISREGISTRATION 30 BY 30 PIXEL 03/17/81 PAGE 3

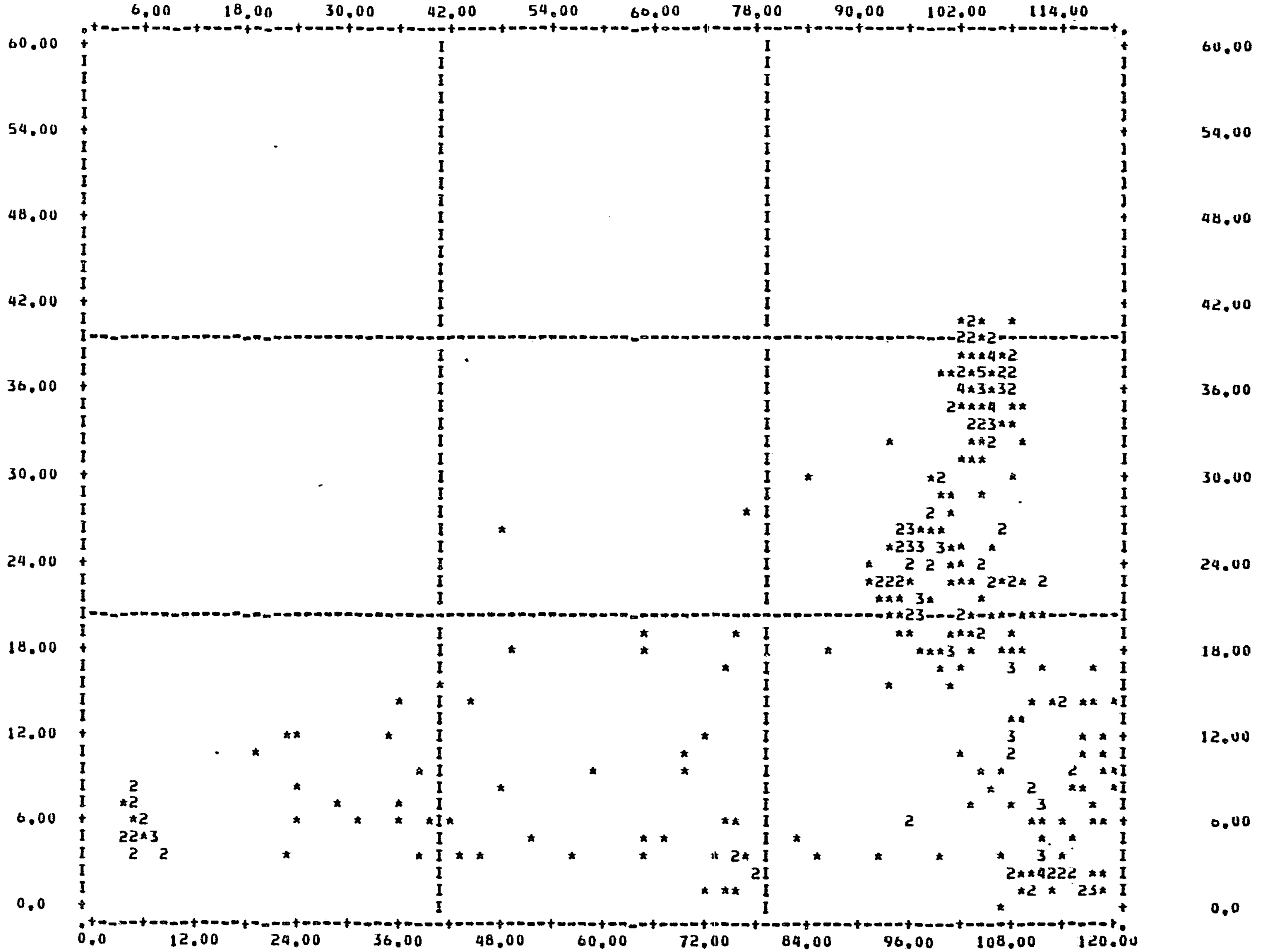
FILE NONAME (CREATION DATE = 03/17/81)
SCATTERGRAM OF (DOWN) GREEN (ACROSS) BRIGHT



ORIGINAL PAGE IS
OF POOR QUALITY

PATTERN-14 DAY=214 V=4.0 R=0.0 NO MISREGISTRATION 20 BY 20 PIXEL 03/17/81 PAGE 5

FILE NONAME (CREATION DATE = 03/17/81)
SCATTERGRAM OF (DOWN) GREEN (ACROSS) BRIGHT



CONCLUSIONS

- The Impact of f_a, the Within Pixel Crop Mixing Distribibition is Potentially Large
- Even When the Pure Pixels Have Nice, Well Behaved Distributions, Mixed Pixels can Have Complicated Distributions

THROUGH-THE-SEASON TECHNIQUES RESEARCH

Project: Supporting Research

Project Element: Pattern Recognition - Corn/Soybeans

Task: Through-the-Season Estimation

Performing Organizations: ERIM/UCB

Presentor: Christian Pestre

March 23, 1981

OUTLINE OF PRESENTATION

- Problem Addressed
- Problem Context
- Our Conceptual Approach
- Our Technical Approach
- Our Programmatic Approach
- Concluding Remarks

PROBLEM ADDRESSED

- Area Estimates of Target Crops Are Required Periodically Throughout the Growing Season, But Current Technology Supports Only Near-Harvest Estimates
- Focus of Research is on Through-the-Season (TTS) Techniques for:
  - Corn and Soybeans
  - Argentina and Brazil

USDA FORECAST ACCURACIES FOR COUNTRY/CROP PRODUCTION ESTIMATES

Country/Crop	Forecast			
	Early Season	Mid-Season	Pre-Harvest	At-Harvest
		Actual Now		
Argentina/Corn	17/90	--	18/90	22/90
Brazil/Corn	34/90	--	37/90	37/90
		Goal 1985		
Argentina/Corn	30/90	--	50/90	75/90
Brazil/Corn	50/90	--	60/90	80/90

THROUGH-THE-SEASON AREA ESTIMATION

DESIRABLE OUTPUT OF A THROUGH-THE-SEASON PROCEDURE:

- Acreages of Target Crops Present on Fields
- Estimate of Accuracy Allowing User to Compare this Information with Information from Other Sources
- Ancillary Information on Factors Affecting Acreages, Allowing Projections to At-Harvest, e.g.,
    - Status of Earlier Crops
    - Current Status of Target Crops

THROUGH-THE-SEASON AREA ESTIMATION

CONTEXT:

- Through-the-Season Estimation Requires New or Different Uses of Landsat Information, that Depend on:
  - Local agronomy
  - Current year crop calendars
- Economic Statistics can be Used in Econometric Models in Order to Complete Partial Answers from Landsat
  - Acreages, productions, weather, prices, etc.
  - Not available at segment-level
- EStimation Will Combine Observation and Prediction
  - Some features translate farmer's intention
  - But intention may change due to weather or prices

THROUGH-THE-SEASON AREA ESTIMATION

OUR CONCEPTUAL APPROACH:

- Direction of Our Efforts
  - •• We must consider the general problem in order to understand what, of general value, can come from Landsat, but:
  - •• Our primary technical emphasis will be on developing the Landsat information extraction technology

THROUGH-THE-SEASON AREA ESTIMATION

OUR CONCEPTUAL APPROACH (continued):

- Landsat Information
  - Take advantage of local agronomic understanding to know information content of Landsat observables and develop extraction of appropriate features
  - Use adjusted crop calendars for labeling guidelines as well as quantitatively, for estimating ratios
  - Use all land cover classes
- Econometric Models
  - Produce ratios applicable to Landsat classes
  - We may not use them at segment level
  - Envisage Landsat inputs (indicator classes, this year's data)
- Merge Informations from Different Sources into a Best TTS Estimator (see Example)

  Expected Increasing Importance of Landsat and Collateral as Season Progresses

THROUGH-THE-SEASON ESTIMATOR

- Example
  - May Have Competitive Estimates
    - Medium-quality [corn] vs. [soybean] separability → P_1 corn
    - Good [SC] estimate + ratio (ρ) → P_2 corn
  - Model for best estimate
    - $P = \alpha P_1 + \beta P_2$ where α, β function of variance of P_1, P_2
- More Generally, How to Merge Outputs from Different Paths

$$P = \alpha [\text{Crop}]_{ECON} + \Sigma \beta_i \left([\text{Group}]_{LS} \; \rho_{\text{crop}/\text{group}\; ECON, LS} \right)_i + \gamma [\text{Crop}]_{LS}$$

- α, β_i, γ function of variances and covariances of component estimators (need for accuracy self-assessment)

  vary through-the-season (Landsat increases)

THROUGH-THE-SEASON AREA ESTIMATION

OUR TECHNICAL APPROACH:

- Refine Baseline Procedure Components
  - Spatial stratification (Blob)
  - Spectral stratification (DFS)
  - Labeling features - hierarchial labeling
    - target crops as well as other classes
- Develop Ratios
  - Econometric models
    - statistics only
    - use of Landsat classes as inputs
  - Other segments
  - Crop calendars
- Develop Accuracy Assessment
  - Empirical
  - Self-assessment
    - parameters to feed models, e.g.,
      - analyst's label confidence
      - timing of acquisitions

THROUGH-THE-SEASON ESTIMATION

RATIOS

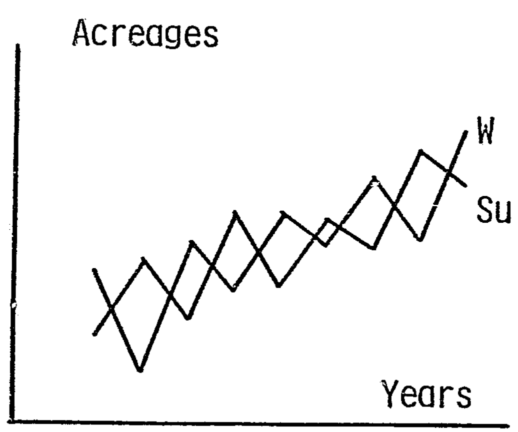
From Model Based on Historical Statistics

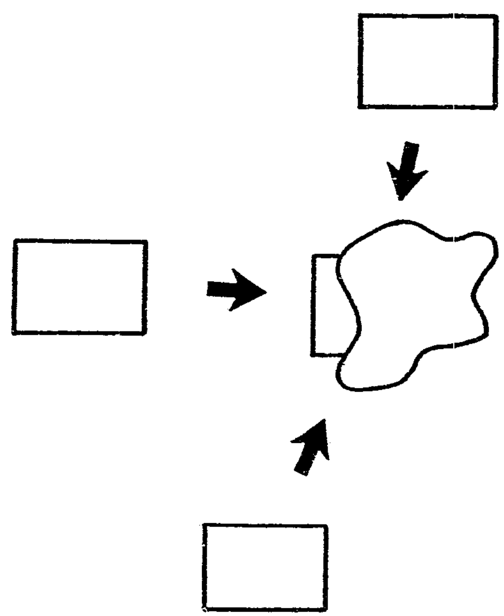
From Other Segments

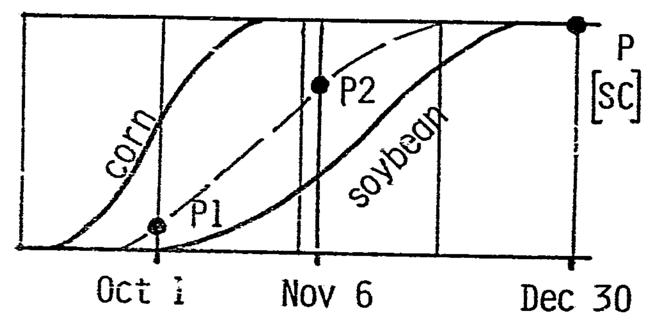
From Crop Calendars

Current Year

Planting Observed on Segment:







EXAMPLE OF SHAPE OF AN ECONOMETRIC MODEL

Inputs

- This Year's Crop Group and Type Estimates from Landsat
- Historical Crop Acreages
- Historical Prices
- Other Relevant Factors (e.g., government policy, meteorological data)

Development

- Modified Agricultural Econometric Models (use this year's input)
- Use of USDA Data on U.S.
- Extend to Foreign Countries (Argentina, Brazil)

Example

Let CC_{it} be acreage of crop class i in year t (e.g., summer crops, winter small grains) $i=1,\ldots,n$

C_{jt} be acreage of crop type j in year t (e.g., corn, soy)

Let $\Delta CC_{it} = \dfrac{CC_{it} - CC_{it-1}}{CC_{it-1}}$, $\Delta\widehat{CC}_{it} = \dfrac{\widehat{CC}_{it} - CC_{it-1}}{CC_{it-1}}$ estimated ΔCC_{it} from Landsat

$$\widehat{\left(\frac{C_{jt}}{CC_{it}}\right)} = f(\Delta\widehat{CC}_{1t}, \ldots, \Delta\widehat{CC}_{nt}, C_{jt-1}/CC_{it-1}, \text{prices})$$

THROUGH-THE-SEASON AREA ESTIMATION

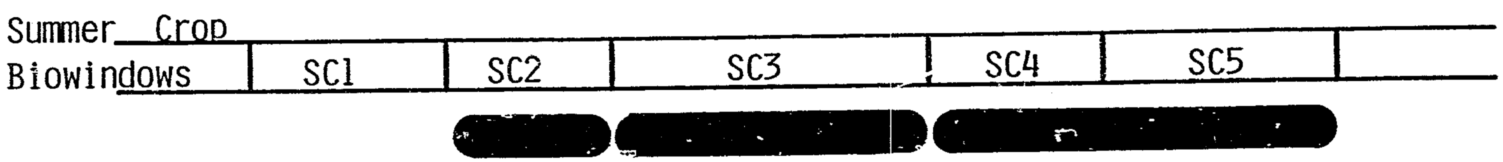
OUR PROGRAMMATIC APPROACH:

- Progression of Supporting Research for
  - Discrete
  - Continuous
  - Continuous, multiyear Landsat
- FY81 Emphasis on Discrete Case

ESTIMATORS FOR DISCRETE INTERVALS

- Start from Landsat TTS Guidelines Developed Last Year
- Investigate Ratio Methods Using Non-Landsat Data
- Build Experimental TTS Techniques A.S.A.P. for Different Times of the Growing Season (see Examples)
  - Modified baseline procedure components
  - And/or separate analysis routines
- Select Segments from Foreign Similarity Region
- Develop a TTS Data Simulation Capability
- Make Trial Runs with Real and Simulated Data, to Gain a Better Perception of What is Needed for TTS Techniques
- Modify Techniques, as Indicated
- Initiate Study of Error Characterization

EXAMPLE OF DISCRETE ESTIMATORS:



SC4, SC5:
- Quasi-Baseline
- Ratios from Other Segments
  (when missing acquisitions)

SC3 :
- [C], [S], Using Through-the-Season Labeling
- Good $[SC]_{LS}$ + Ratio (Econometric, Other Segments)
- Best Estimate $\alpha P_1 + \beta P_2$

SC2 :
- Emergence Not Completed, Use C.C. Ratios for [SC]
- [SC] + Ratio (Econometric)
- Crop Calendar Ratio for C/S (By Rate of Planting)

CONTINUOUS ESTIMATOR

- Objective:

  Estimation of Any User Designated Time Using the Then-Best Estimator

- Approach:

  - Refine "discrete" technology
  - Include error self-assessment
  - Incorporate a multisource TTS estimator
  - Use profile technology
  - For efficiency, take advantage of prior processing on same segment

CONTINUOUS ESTIMATOR, MULTIYEAR LANDSAT

- Early in the Season, Comparison with Previous Year Will be Helpful for Landsat Information Extraction, e.g.,
  - Crop mix
  - Crop calendars
  - Crop rotations
- Use of Multiyear Acquisitions Helps to Improve Estimates of Crop Area Shifts, Therefore Enhances Econometric Prediction (of Ratios)

THROUGH-THE-SEASON AREA ESTIMATION

CONCLUDING REMARKS:

- Need Local Agronomic Understanding Which Reveals Information Content of Landsat Features, Thus Drives Information Extraction Efforts
- Need TTS Features for Other Crops as Well as for Target Crops, Thus Need Adjusted Crop Calendars for all Crops
- Need Econometric Models at Some Times to Reach the Final Answer
  - Should incorporate current-year Landsat inputs
  - Will give their full potential with Landsat inputs in a multiyear context

CORN AND SOYBEANS

P-2 DEVELOPMENT

A Technical Gestalt

Presented by: Claire Hay/UCB

With F. Pont and R. Kauth/ERIM

March 23, 1981

Quarterly Technical Interchange Meeting

Supporting Research Division, Johnson

Space Center, Houston, TX 77058

CORN AND SOYBEANS P-2 DEVELOPMENT

Outline

Introduction

- P-2 Initial Design
- P-2 Research Requirements
- Resource Considerations

INTRODUCTION

- Objectives and Technical Thrust of P-2
- Approach

C-2

OBJECTIVES AND THRUST OF P-2

- Objectives of P-2
  - Increased efficiency in area estimation
  - Reduced turnaround time from data acquisition to estimates
  - Extraction of other information from remotely sensed data
    - Indicators of crop condition
    - Spectral indicators which support crop yield

- Technical Thrust of P-2
  - Full frame multitemporal registered Landsat data *
  - Flexible stratification and sampling strategies
  - Intensive use of machine processing
  - Analyst critical overview of processing
  - Full frame based features for condition assessment

*The options for "Full Frame Registration" are discussed in later viewgraphs.

APPROACH TO P-2 DEVELOPMENT

- Chicken or egg?
  - If you could implement P-2 you could conduct research
  - If you had the research you could design P-2
  - If you could design P-2 you could implement P-2
- The Evolutionary Approach:
  - Both chickens or eggs exist
  - Both evolved jointly

APPROACH TO P-2 DEVELOPMENT

- Do an Initial Design Based on Gestalt of LACIE/TY Experience
- Use Preliminary Design to Identify Research Issues Which Will Affect Later Design Decisions
- Implement a (Compromise) P-2 Research Testbed
  - Based on preliminary design
  - Within resource constraints
  - Flexible usage
- Conduct Research Both Outside and Inside the Testbed Environment
- Evolve Advanced Design Based on Research

P-2 INITIAL DESIGN

- Past Experience - Summary
- System Considerations
- Conclusions from Past Experience and System Considerations
- An Initial P-2 Design (The Model TP2)

BACKGROUND

(Past Research Related to P-2)

- UCB Study
  - Analyst gives quick proportion estimate, p', for every possible segment
  - Analyst provides best accuracy proportion estimate, $\hat{p}$, for a sample of segments
  - Regress $\hat{p}$ and p' and produce a total area estimate based on regression
- Procedure B in Kansas (ERIM)
  - Across segment clustering
  - Developed procedure for choosing representative training units
  - Extension of training to population
- Multisegment Estimation (IBM)
  - CLASSY clusters
  - Developed procedure for choosing representative training units
  - Extension of training to population

BACKGROUND (Continued)

(Past Research Related to P-2)

- Multisegment Estimation (ERIM)
  - Across segment clustering
  - Data normalization to remove some of between segment variability
  - Dynamic strata (UCB's degree days and precipitation strata)
- Cluster Sampling Inefficiency (LARS)
  - Used various sample unit sizes ranging from LACIE segment to single pixels
  - Total number of pixels labelled a constant
  - Measure variance as function of sample unit size
  - Factor of 8 available in sampling efficiency, by labelling isolated pixels

OVERALL CONCLUSIONS FROM PREVIOUS EXPERIENCE

- Regression Techniques Have a Higher Potential for Training Gain Than Multi-segment Stratified Areal Estimation Techniques
- Large (LACIE) Segments Limit Sampling Variance Due to Inefficiency of Cluster Sampling
- Variations in Signatures Limit the Area Over Which Training is Applicable and Therefore Limit the Training Gain Which can be Achieved
- General LACIE/TY Experience
  - About 3 sample segments/full frame area
  - Sampling variance about equal to measurement variance

n is the number of analyst decisions

f is the inefficiency factor due to cluster sampling (the cost per analyst decision is an important ingredient of total cost)

LARS study shows f to be about 8. For LACIE, TY the two terms, $f\,\frac{\sigma_s}{n}$, $\frac{\sigma_m}{n}$ are about equal. Hence in order to reduce cost significantly both f and σ_m must be reduced.

The primary source of σ_m is poor or marginal acquisition histories. Hence in order to reduce cost significantly, the inefficiencies of cluster sampling must be reduced and the acquisition histories must be improved. Both these factors point to a requirement for a flexible sampling strategy.

FRAMEWORK FOR REMOTE SENSING BASED RESOURCE INVENTORY SYSTEM

(Generic)

- User Request
  - Data acquisition/survey/evaluate
  - Initial response
  - Stratify
    - Sample
    - Evaluate
      - Analyze (measure)
      - Evaluate
    - Aggregate/Estimate
    - Evaluate
  - Aggregate/Estimate
  - Evaluate
- Report

- Analyze
  - Stratify
    - Sample
    - Evaluate
      - Label
    - Aggregate
  - Aggregate
- Evaluate

MODEL T P-2 (Page 1)

- User Request (Identify Region in World Coordinates)
  - Data Survey
    - Acquire all revelent P-Tapes
    - Screen for cloud cover/compile multi-acquisition bit mask/assign acquisition history quality values/display on screen with region overlay and APU overlay
    - Evaluate sample adequacy
- Initial Response to User
  - Stratify
    - Green wave
    - Machine stratify
    - Analyst preliminary estimates of proportions from one good acquisition

options which imply research

MODEL T P-2 (Page 2)

- Sample
  - Use cloud mask, apply to A-Tapes
  - 64 x 64 segments (say), within 96 x 96 element cookie cutter
  - Register 64 x 64's overnight
  - Overlay segment locations on region map
- Analyze
  - 512 x 512 display screen allows 16 temporal segments to be displayed at 4 reselms/pixel
  - Adapt C/S baseline to small segments
    - preprocessing, BLOB, DFS, TPC's
    - 10 - 20 dots to label
    - analyst aids on second screen
  - Using only very good acquisition histories
  - Do for 20 - 30 segments
- Evaluate
  - Internal consistency checks

MODEL T [illegible]-2 (Page 3)

- Aggregate to Strata
- Evaluate Strata Variance
- Aggregate to Region
- Evaluate Region Variance

- Report

MODEL T P-2 (Page 4)

- Resource Constraints
  - Equipment is available on a non-interference basis

    (2 512 x 512 RAMTEK displays with overlay and 8 bit grey scale or color)

    (2 VTM 100 terminals which can be used to display analyst aids)
  - Software must be developed

SCOPE OF P-2 RESEARCH

- CREATE AN OVERALL STRUCTURE FOR P-2
  - C/S consortium, P-2 technology phase
  - Coordination with Sampling & Aggregation Research
- DEVELOP CANDIDATE TECHNIQUES SUITABLE FOR INCLUSION IN P-2
  - Dynamic stratification
  - Multisegment estimation
  - Change detection
  - Full frame features*
  - Methods of clustering the new USDA strata *
    - •• Static variables (soil type, etc.)
    - •• Dynamic variables (green wave, etc.)
  - Regression approach to aggreate machine and analyst proportion estimates*
- RESEARCH TO ASSIST IN P-2 DESIGN DECISIONS
  - Cost/error model for P-2
  - Sample unit size, interpretive unit size, interaction
  - Cloud cover analysis for acquisition histories*

*Related research being conducted under other tasks (not P-2).

P-2 RESEARCH TASKS

- Corn and Soybeans (P-2 Research)
  - Dynamic stratification
  - Multisegment estimation
  - Change detection
- Sampling and Aggregation (Generic Research)
  - Sample unit size, interpretive unit size, interaction
  - Methods of clustering the new USDA strata
    - Static variables (soil type, etc.)
    - Dynamic stratification (green wave, etc.)
  - Regression approach to aggregate machine and analyst based proportion estimates

DYNAMIC STRATIFICATION
and
MULTISEGMENT ESTIMATION

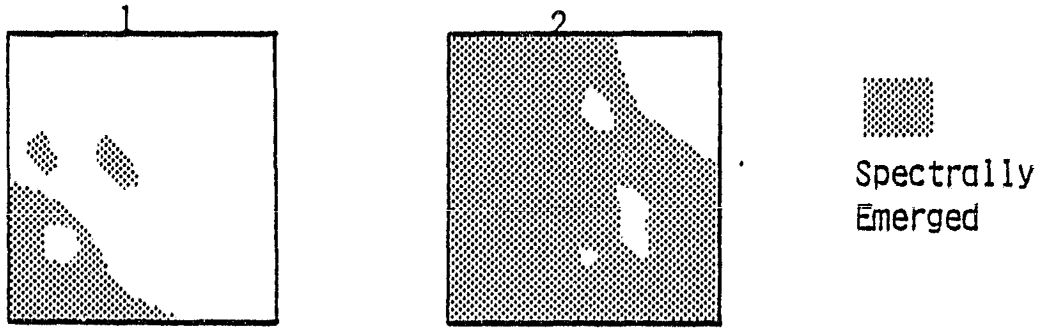
- Background
  - Profile technology has shown that a shift different can make a large difference in the spectral response of a given crop
  - Times of planting and greenup are spatially correlated
  - "Signature extension" should be limited to regions where spectral/temporal response of the crops are expected to be the same

FIRST STAGE SAMPLING STRATA

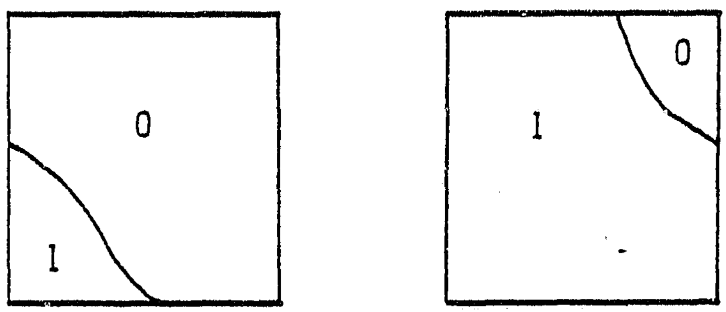
- APU
- Clustered USDA Strata

  Dynamic Partitioning Based on Smoothed "Green Wave"
- Linear Discriminant: GRABS ≥ 6

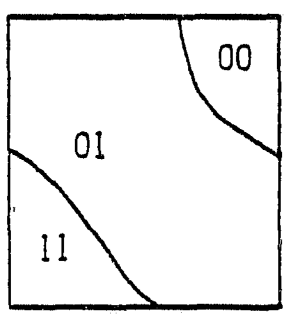
Acquisition 1 | Acquisition 2



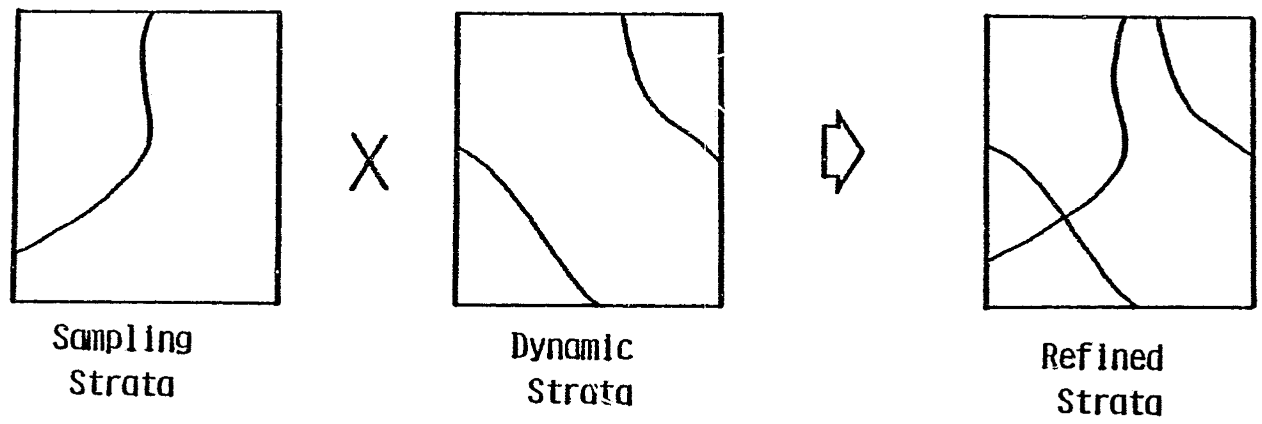
- Spacially Smoothed



- Intersected



COMPOSITE STRATA



- If Data Base is Flexible Then Sample Unit can be Allocated to Refined Strata
- Representative Sample Units for Training
- Extension to Other Units or Entire Strata

ISSUES/PROBLEMS

- CONSTRAINTS ON THE NUMBER OF SAMPLE UNITS MAY NOT ALLOW SUFFICIENT TRAINING
- SMALLER SAMPLE UNIT SIZE MAY ALLOW MORE TRAINING
- MISMATCHING MULTI-TEMPORAL ACQUISITION HISTORY
    - Profile technology may help
    - Full frame sampling could stabilize acquisition history
- "THROUGH THE SEASON" ESTIMATION IS A PROBLEM SINCE THE INCLUSION OF NEW ACQUISITIONS MAY CHANGE THE SUBSET OF TRAINING UNITS
- ATMOSPHERIC AND BACKGROUND EFFECTS MAY MAKE EACH SEGMENT UNIQUE
- EXISTING DATA NORMALIZATION TECHNIQUES MAY EXPLAIN THE BETWEEN SEGMENTS VARIABILITY DUE TO ATMOSPHERIC EFFECTS

SAMPLING AND AGGREGATION RESEARCH (FULL FRAME)

- MOTIVATED BY EXPECTATION THAT P2/FULL FRAME PROCEDURES WILL MERGE MEASUREMENT AND SAMPLING AND AGGREGATION INTO ONE ESTIMATION PROCEDURE
- COORDINATION VIA SERIES OF WORK SHOPS
- JOINT EFFORT TO DEFINE DATA NEEDS AND DATA BASE

SAMPLING AND AGGREGATION TECHNOLOGY SUPPORT

OBJECTIVE

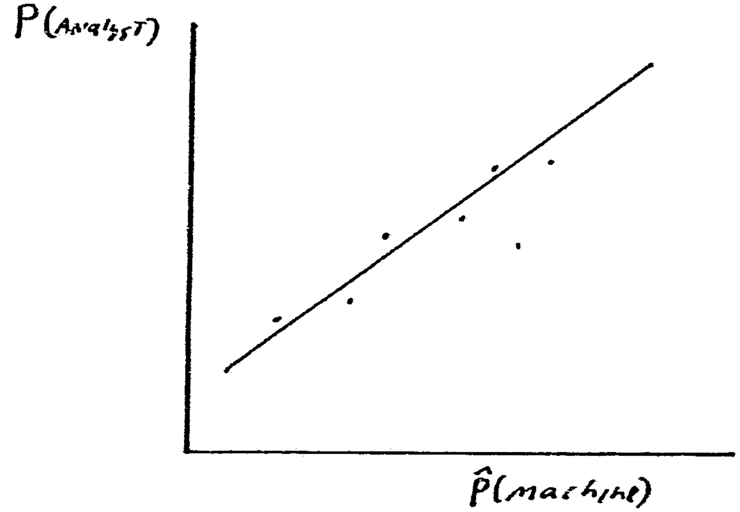
Provide General Support in the Development/Advancement of Generic Full Frame/P2 Technology

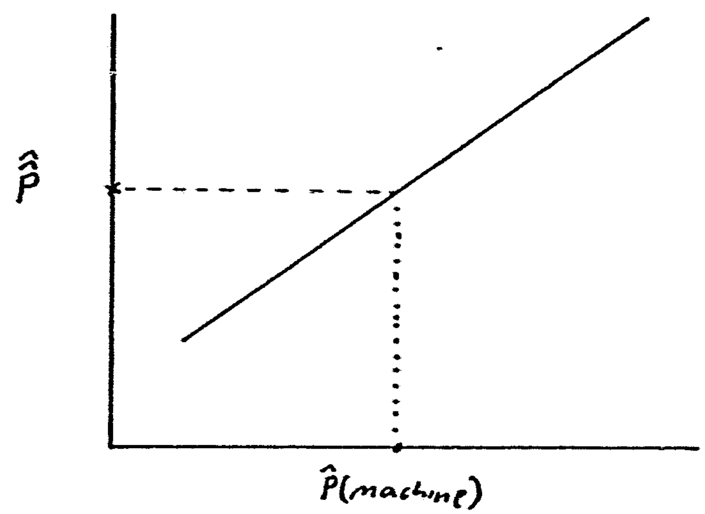
APPROACH

- Take Technical Lead in R&D Support to Full Frame/P-2 Sampling and Aggregation
- Assessment of Performance of Automated Proportion Estimation Relative to Sample Unit Size
- Evaluation of USDA Strata-Other Stratification (Using Different Clustering Approaches)
- Dynamic Stratification/Within-Stratum Variances Estimation
- Investigate the Utility of a Regression Approach to Aggregate Machine and Analyst Labels
- Aid in Developing/Determining Common/Standard Test Data Set

MACHINE/ANALYST REGRESSION/AGGREGATION APPROACH

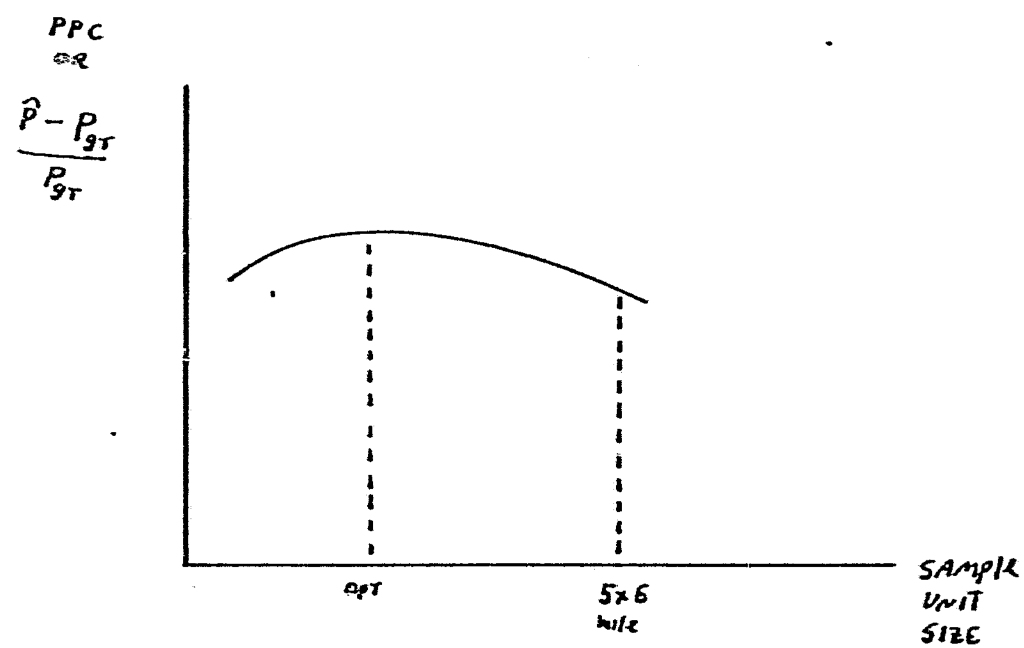
- OBTAIN MACHINE PROPORTION ESTIMATES OVER ALL OR LARGE PART OF SEGMENTS
- OBTAIN ANALYST BASED PROPORTION ESTIMATES ON APPROPRIATELY CHOOSEN SUBSET OF SEGMENTS
- USE REGRESSION TECHNIQUES TO AGGREGATE PROPORTION ESTIMATES

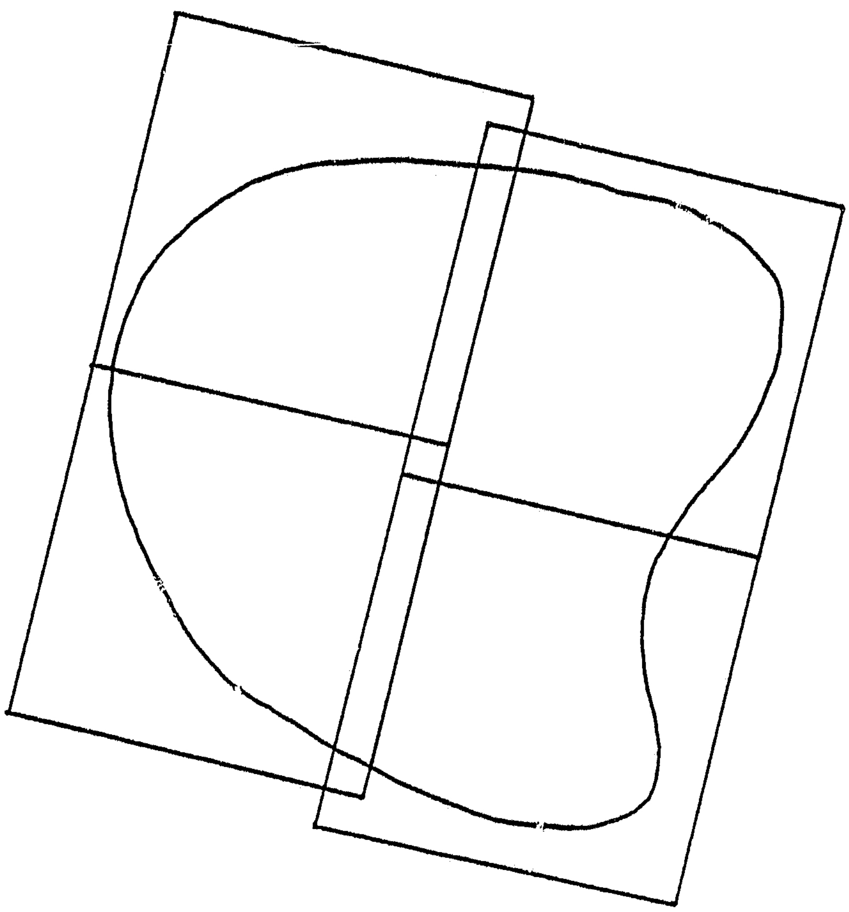


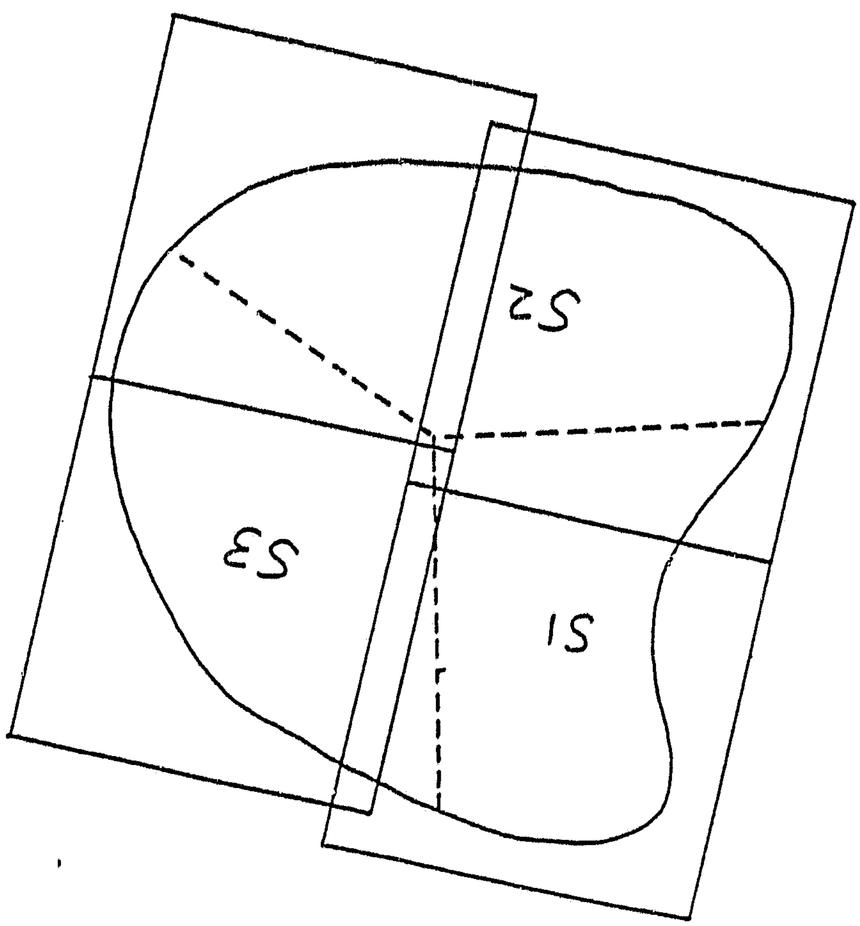


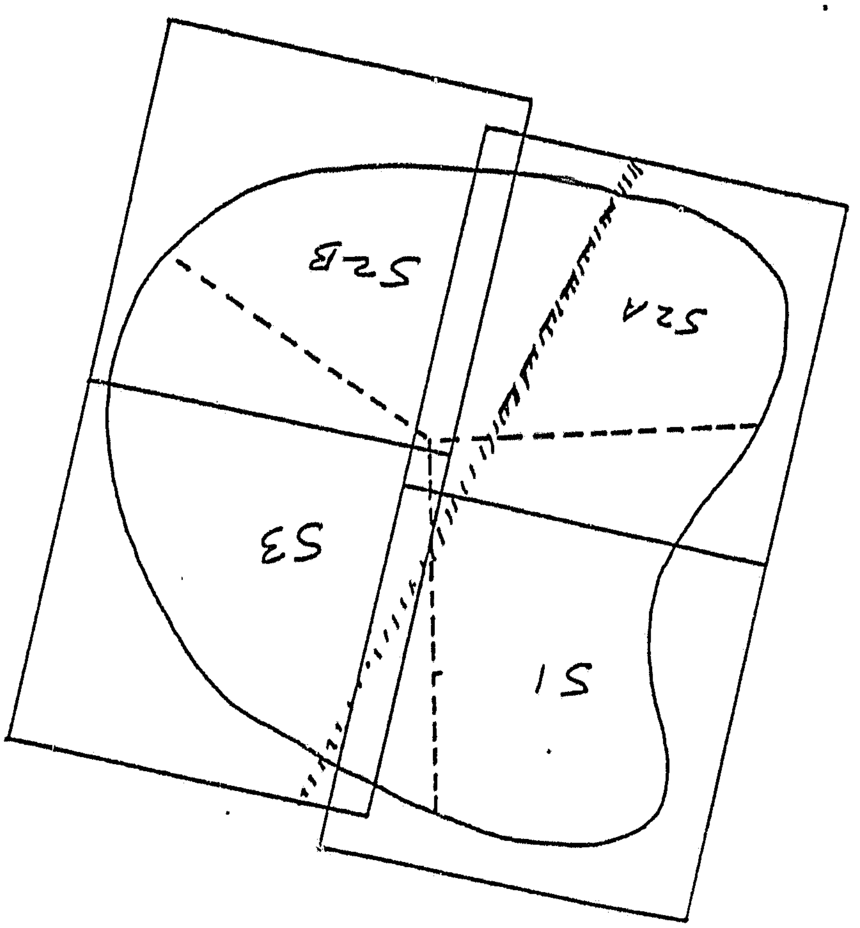
SAMPLING UNIT SIZE STUDY

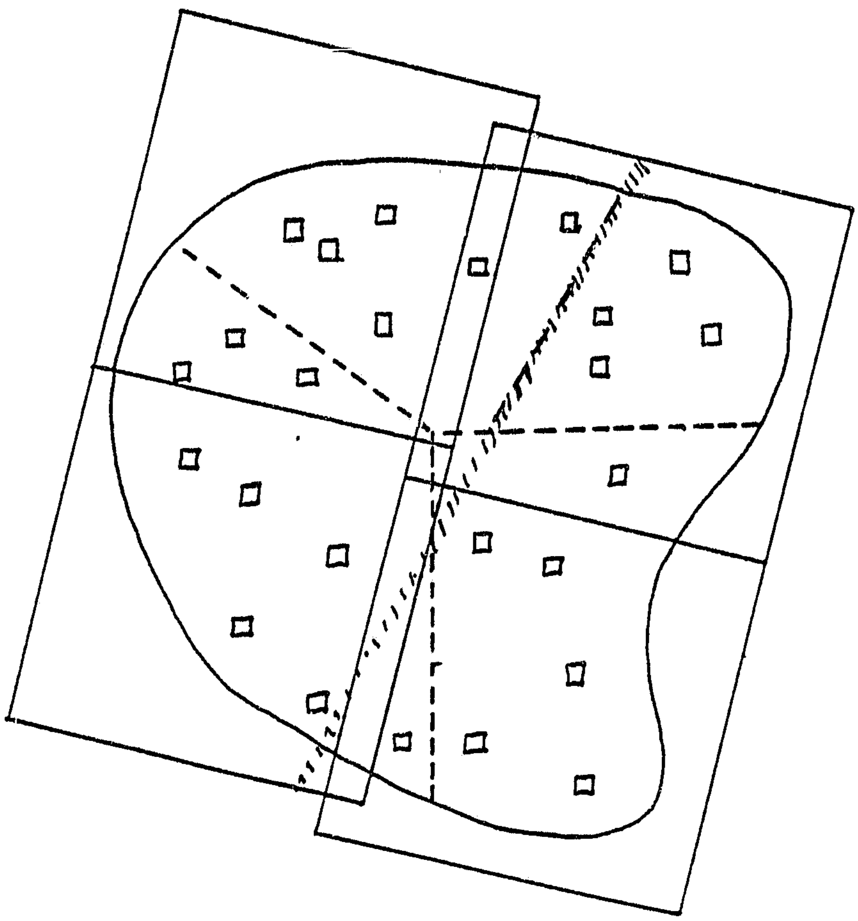
- USE AN AUTOMATIC CLASSIFIER TO STUDY THE EFFECT OF UNIT SIZE ON
  - PPC
  - $\frac{\hat{P} - P_{gT}}{P_{gT}}$
- ASSUMES STRONG CORRELATION BETWEEN ANALYST AND MACHINE BASED ESTIMATES

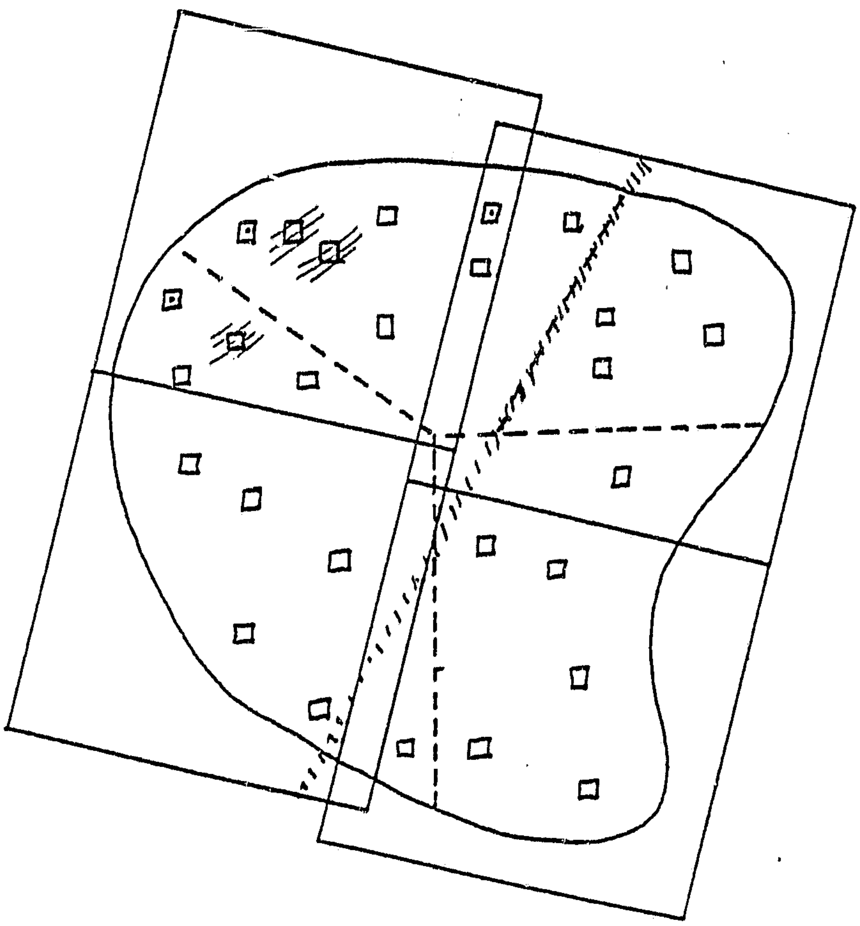





S2
S3
S1


S2-B
S2A
S3
S1





P-2 AND FULL FRAME

- Rationale
  - Detailed (analyst based) decisions are (or will be) the single highest recurring cost element as computing and data management costs reduce in the future
  - Flexible full frame based sampling strategies can greatly improve sampling efficiency by distributing these high cost decisions over full frames
  - To achieve a total reduction in cost the accuracy of decisions will also have to be improved since, currently, measurement error and sampling variance contribute equally to total variance
  - The primary perceived source of decision error is in inadequate acquisition histories due to cloud cover losses
  - Flexible full frame based sampling strategies may improve acquisition histories by allowing resampling when acquisitions are lost

ARGENTINA FIELD TRIP
(16-30 FEBRUARY 1981)

BUZZ SELLMAN
BYRON WOOD

ERIM/UCB

QUARTERLY TECHNICAL INTERCHANGE MEETING
MARCH 23-26, 1981

OBJECTIVES OF ARGENTINA FIELD TRIP

- MEET AGRONOMY AND REMOTE SENSING PEOPLE
- GATHER DATA
- ESTABLISH RAPPORT FOR FUTURE NEGOTATIONS AND COLLABORATIVE WORK ON AgRISTARS

16	17	18	19	20
Buenos Aires	Castelar	Field (Northern Buenos Aires Province)	Field (Northern Buenos Aires Province)	Field (Northern Buenos Aires Province)
International Agricultural Service, State Secretariat for Agriculture and Livestock (SEAG)	National Institute for Crop-Livestock Technology (INTA)	Salto	Rojas Gen. Arenales(2)	Junín Bragado
				Buenos Aires
				National Commission for Space Investigations (CNIE)

ERIM/UCB GROUND DATA COLLECTION MISSION
TO ARGENTINA 16-30 FEBRUARY 1981

DAILY ACTIVITY SUMMARY

23	24	25	26	27
FIELD (BAHÍA BLANCA - SOUTHERN BUENOS AIRES PROVINCE)	FIELD (SOUTHERN BUENOS AIRES PROVINCE)	FIELD (SOUTHERN BUENOS AIRES PROVINCE)	FIELD (SOUTHERN BUENOS AIRES PROVINCE)	RETURN TO BUENOS AIRES
VILLARINO	TORNQUIST COL. SUÁREZ	PUÁN (649)	PUÁN (556)	
FIELD (CÓRDOBA)	FIELD (CÓRDOBA/ SANTE FE)	FIELD (CÓRDOBA)	RETURN TO BUENOS AIRES	INFORMAL INFORMATION EXCHANGE AT SEAG
RÍO CUARTO JUAREZ CELMAN	SAN JUSTO SAN MARTIN	SAN JUSTO		
BUENOS AIRES				
PROCESSING CENTER (CNIE)				

ERIM/UCB GROUND DATA COLLECTION MISSION
TO ARGENTINA 16-30 FEBRUARY 1981

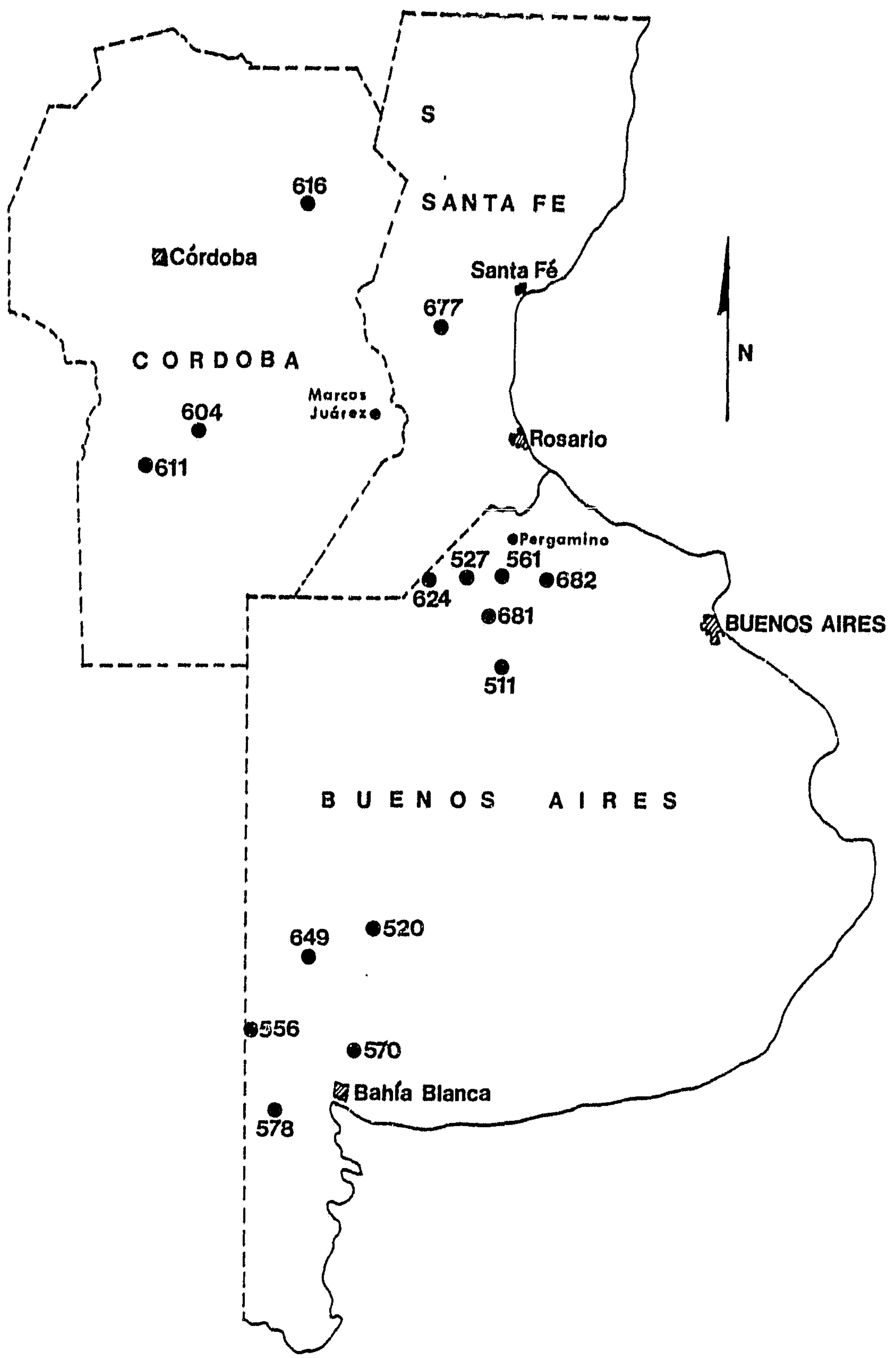
DAILY ACTIVITY SUMMARY

16 February 1981

Meeting At
Argentina Ministry of Economy,
State Secretariat for Agriculture and Livestock (SEAG)

Julia Elena Rivarola	- Deputy Director, International Agriculture Service
Ezequiel A. Fonseca	- Advisor, Subsecretariat for Economic Agriculture
Eduardo Anchubidart	- Chief, Agricultural Estimates
Carlos O. Scoppa	- Coordinator, Soil Survey Program, National Institute for Crop-Livestock Technology (INTA), Castelar
Nestor A. Darwich	- INTA, Balcarse
Carlos M. Liberatori	- INTA
Carlos A. Senigagliesi	- Crop Production, INTA, Pergamino
Jorge E. Nisi	- INTA, Marcos Juárez
Adelqui L. Damilano	- Coordinator, Corn Program
Norberto V. Rodriquez	- National Statistical Service for Economy and Rural Living
Claudio A. Fonda	- Department of Agricultural Estimates
Miguel A. Abraham	- Subsecretary for Natural Resources and Ecology
James Parker	- Agricultural Attache, USDA(FAS), Buenos Aires
Byron Wood	- University of California-Berkeley
Ed Sheffner	- University of California-Berkeley
Gene Thomas	- Environmental Research Institute of Michigan
Buzz Sellman	- Environmental Research Institute of Michigan

SAMPLE SEGMENTS VISITED IN ARGENTINA



20 February 1981

Meeting At
National Commission for Space Investigations
(CNIE, Vicente Lopez)

J.J. Tosso - National Commission for Space Investigations

Julia Elena Rivarola - International Agriculture Service, SEAG

Miguel Conde Prat - Coordinator, Crop-Livestock Estimates, SEAG

Eduardo Anchubidart - Chief, Agricultural Estimates

Cecilia Espoz - Agronomist, CNIE (UNDP/FAO Remote Sensing Project)

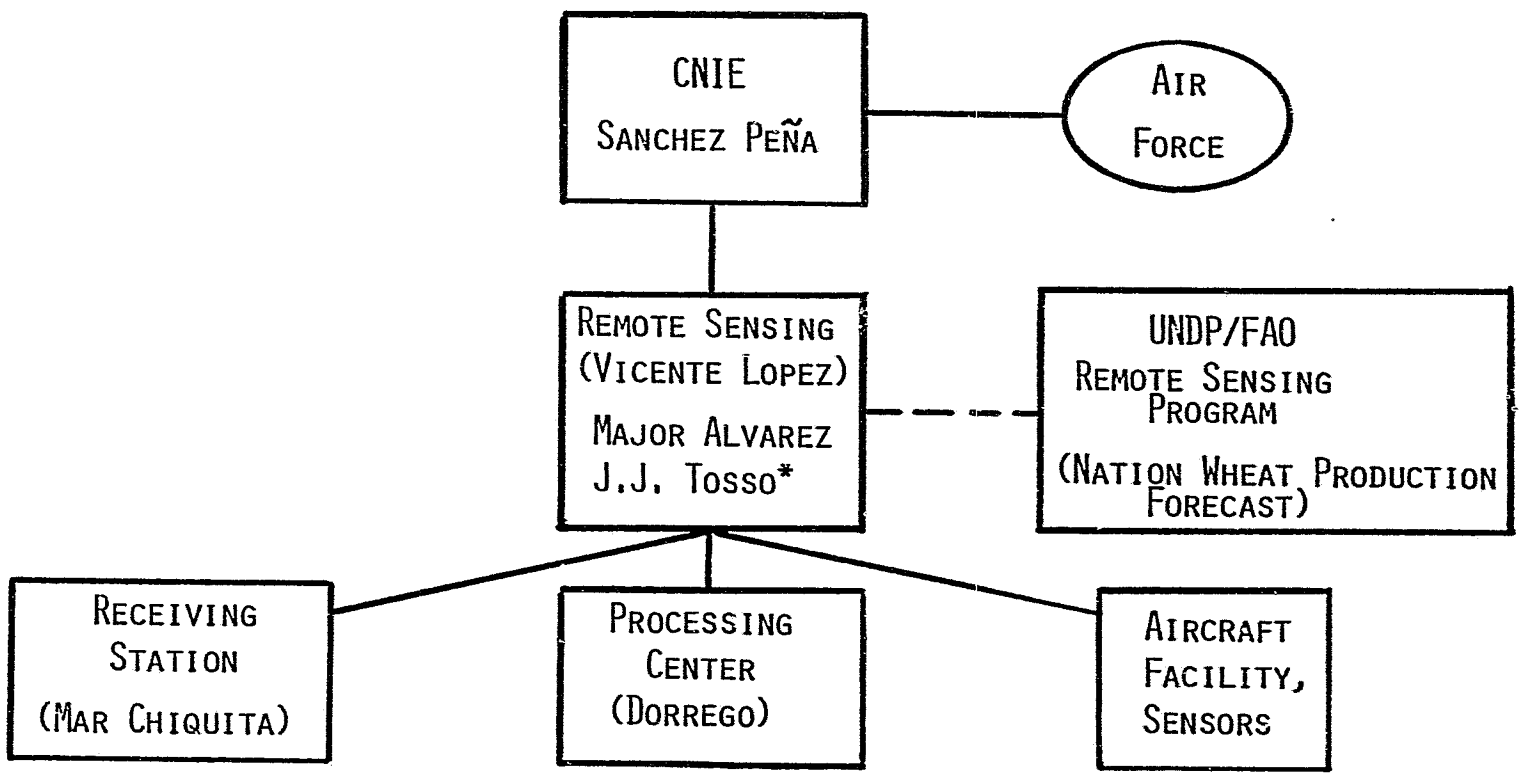
Eugenio E. Portalet - Meteorologist, CNIE (UNDP/FAO Remote Sensing Project)

Buzz Sellman - Environmental Research Institute of Michigan

23 FEBRUARY 1981

MEETING AT PROCESSING CENTER, CNIE (AV. DORREGO)

LUIS SOCOLOVSKY - CHIEF, PROCESSING CENTER
VICTOR D. LARIAS - DATA SERVICES
SEVERINO FERNANDEZ- SOFTWARE DEVELOPMENT
ALEJANDRO ZABALA - ELECTRONIC TECHNICIAN



*"RETIRED" AS OF DECEMBER, 1980.

30 February 1981

Meeting At
Argentina Ministry of Economy,
State Secretariat for Agriculture and Livestock (SEAG)

Antonio T. Parsons	- Director, International Agriculture Service
Julia Elena Rivarola	- Deputy Director, International Agriculture Service
Ezequiel A. Fonseca	- Advisor, Subsecretariat for Economic Agriculture
Eduardo Anchubidart†	- Chief, Agricultural Estimates
Claudio Fonda*	- Department of Agricultural Estimates
Miguel Abraham*	- Subsecretary for Natural Resources and Ecology
Carlos Scoppa*	- Coordinator, Soil Survey Program, National Institute for Crop-Livestock Technology (INTA), Castelar
Nestor Darwich*	- INTA, Balcarse
J.J. Tosso†	- National Commission for Space Investigations
Cecilia Espoz*	- Agronomist, CNIE (UNDP/FAO Remote Sensing Project)
Eugenio Ernesto Portalet	- Meteorologist, CNIE (UNDP/FAO Remote Sensing Project)
James Parker	- Agricultural Attache, USDA(FAS), Buenos Aires
Buzz Sellman	- Environmental Research Institute of Michigan
Dave Hicks	- Environmental Research Institute of Michigan

---

†Co-Director, UNDP/FAO Remote Sensing Project (Wheat)

*We had closest contact with these people (field work).

HDDT LANDSAT DATA AVAILABLE FROM ARGENTINA GROUND STATION FOR PAMPA REGION

PATH/ROW	DATE	CC*	CCT (YES/NO)	AGRISTARS SEGMENT NUMBERS
241/85	10/24/80	0	YES	
241/86	10/24/80	1010		
242/82	11/12/80	0		
242/83	9/ 1/80	0	YES	
	9/19/80	0	YES	
	11/12/80	0	YES	
242/84	9/ 1/80	0100		
	9/19/80	0		
	10/25/80	0		
	11/12/80	0		
242/85	9/ 1/80	0		
	9/19/80	0		
	10/25/80	0	YES	
	11/12/80	0		
242/86	9/ 1/80	0		
	9/19/80	0		
	10/25/80	0010		
	11/12/80	0		
	12/18/80	0011		
243/81	11/13/80	0		
	9/ 2/80	2100		
243/82	9/ 2/80	0		
243/83	9/ 2/80	0	YES	
243/84	9/ 2/80	0		
	9/20/80	0		
243/85	9/ 2/80	0		
	9/20/80	0		
	10/26/80	0		
243/86	9/ 2/80	1010		
	9/20/80	0	YES	
	10/26/80	0		
243/87	9/ 2/80	0023		
	9/20/80	0	YES	
	10/ 8/80	0	YES	
	10/26/80	1010		

HDDT LANDSAT DATA AVAILABLE FROM ARGENTINA GROUND STATION FOR PAMPA REGION

(PAGE 2)

PATH/ROW	DATE	CC*	CC† (YES/NO)	AGRISTARS SEGMENT NUMBERS
244/81	9/ 3/80	0		
	9/21/80	0	YES	
	10/ 9/80	0	YES	
	11/14/80	0		
244/82	9/ 3/80	0		
	9/21/80	0		
	10/ 9/80	1111		
	11/14/80	0		
244/83	9/ 3/80	0		
	9/21/80	0		
	10/ 9/80	0001		
	11/14/80	0		
	12/20/80	0		
244/84	9/ 3/80	0		
	9/21/80	0		
	10/17/80	0		
	11/14/80	0001		
	12/20/80	0		
244/85	9/ 3/80	0		
	9/21/80	0		
	11/14/80	0301		
	12/20/80	0		
245/82	9/ 4/80	0		
	9/22/80	0	YES	
	11/15/80	0		
245/83	9/ 4/80	0	YES	
	9/22/80	0		
	12/21/80	0		
245/84	9/ 4/80	0		
	9/22/80	0		
	12/21/80	0		

*CC - CLOUD COVER LISTED BY QUADRANTS,

1	2
3	4